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ON THE POST-EMBRYONIC DEVELOPMENT OF THE MALE GENITAL ORGANS IN ALEURODIDÆ (HOMOPTERA)

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CONTENTS

I. INTRODUCTION

During recent years considerable attention has been paid to the study of the genital organs of insects, specially the external genitalia of the adult male, as the structure of these organs affords characters, important from a taxonomic view point. But the development of the genital organs, particularly of the internal genitalia, has not been pursued with the same enthusiasm, the only recent works being those of Singh-Pruthi (1924, 1925), George (1929), Nel (1929), Metcalfe (1932), Mehta (1934), Else (1934) and Qadri (1940). In the order Rhynchota, the development of the genital organs has been investigated by Christophers and Cragg (1922), Kershaw and Muir (1922), in addition to Singh-Pruthi, George and Metcalfe referred to above. The following account based on the study of *Dialeurodes eugeniæ* Maskell (Aleurodidæ) is an attempt to supplement their observations.

II. MALE GENITAL ORGANS OF *D. eugeniæ* AND OTHER WHITE-FLIES

Before describing the development of the male genital organs, a brief description of these organs in *D. eugeniæ* and a general account in the whole family Aleurodidæ seems desirable. The general description is based on my detailed study of several species of the family (Rakshpal, 1940). The terminology used in this paper is adapted from that employed by Sharp and Muir (1912) and Singh-Pruthi (1925).

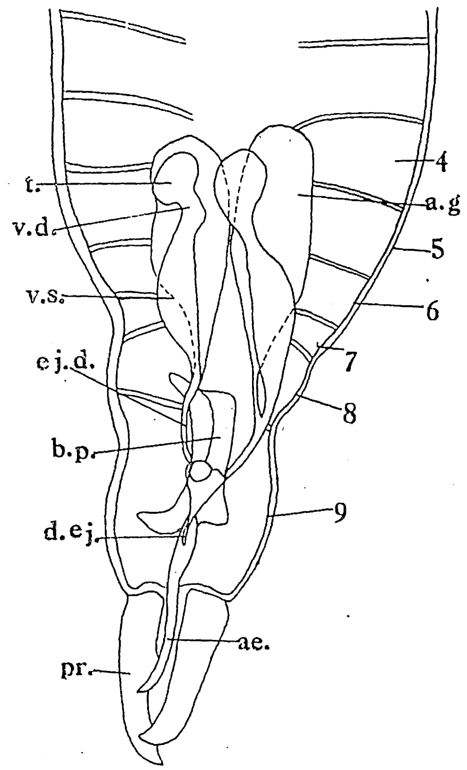

Fig. 1. Male genital organs of the adult. *ae.*, aedeagus; *a.g.*, accessory gland; *b.p.*, basal plate; *d.ej.*, common ejaculatory duct; *ej.d.*, paired ejaculatory ducts; *pr.*, parameres; *t.*, testis; *v.d.*, vas deferens; *v.s.*, vesicula seminalis; 4-9, abdominal segments.

In *D. eugeniæ*, a pair of testes (Fig. 1, *t.*) lies in the fifth abdominal segment, dorsal to the accessory glands (*a.g.*), one on either side of the alimentary canal. Each testis is more or less egg-shaped in outline, dark brown in colour, and consists of a number of lobules, more or less spherical in shape. In each lobule are developed a large number of spermatozoa. The lobules lying towards the outer margin are filled with rounded spermmother cells, those in the middle with much smaller cells—the immature spermatozoa or spermatids, while the lobules on the inner margin of the testis contain mature or nearly mature spermatozoa. From the posterior end of each testis arises the vas deferens (*v. d.*) which is stout and dark yellow in colour. It leaves the testis near the anterior margin of the sixth abdominal segment, and runs posteriorly up to the middle of the eighth abdominal segment. The anterior portion of the vas deferens is more or less constricted and thick-walled, while the posterior portion is very much dilated and thin-walled, thus forming a vesicula seminalis (*v. s.*). Each vesicula seminalis meets the paired ejaculatory duct (*ej. d.*) of its own side in the eighth abdominal segment. The paired ejaculatory ducts are very slender and run posteriorly to open into the common ejaculatory duct (*d. ej.*) about the middle of the

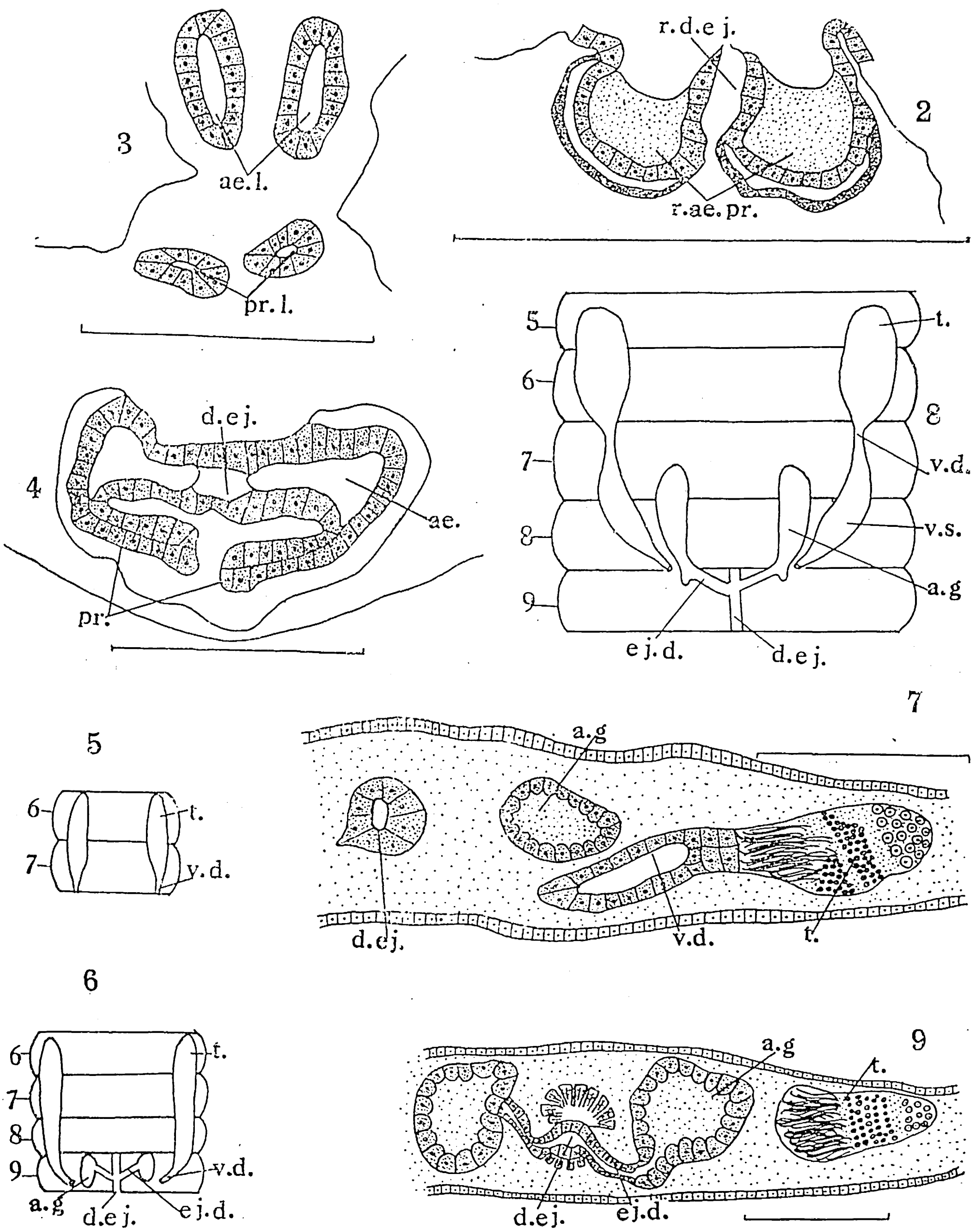

Fig. 2. Transverse section through the posterior abdominal segment of the earlier pupa. *r.ae.pr.*, rudiments of the aedeagus and parameres; *r.d.ej.*, rudiments of ejaculatory duct. Fig. 3. Transverse section through the posterior abdominal segment of the early pupa. Fig. 4. Transverse section through the posterior abdominal segment of the early pupa. *ae.l.*, aedeagus-lobes; *pr.l.*, paramere-lobes. Fig. 5. Diagrammatic, male genital organs of the third larval instar. Fig. 6. Diagrammatic, male genital organs of the early pupa. Fig. 7. Transverse section through the ninth abdominal segment of the early pupa. Fig. 8. Diagrammatic, male genital organs of the late pupa. Fig. 9. Transverse section through the ninth abdominal segment of the early pupa. (Unless otherwise stated, lettering as in Fig. 1. The scale line in the figures represents 0.05 mm.)

ninth segment. At the point of the junction of each vesicula seminalis and the paired ejaculatory duct, open the ducts of the accessory gland. The latter are stout, more or less club-shaped organs, which are dark brown in colour and occupy a ventro-lateral position, one on either side of the alimentary canal, extending from the fifth to the middle of the eighth abdominal segment. They are thin-walled and contain some fluid.

The external genitalia consist of a median ædeagus (*ae.*) and a pair of parameres (*pr.*), while the subgenital plates found in several other families of Homoptera are absent.

The male genital organs of other species of the family Aleurodidæ show some variations, as compared with those of *D. eugeniæ* described above. In *D. dissimilis* Quaint. and Baker, the testes lie ventro-laterally in the sixth abdominal segment. In *Trialeurodes bicolor* Lamba, the vasa deferentia are very slender and are not dilated to form vesiculæ seminales. For details of the external genitalia a reference may be made to the writer's paper quoted above.

III. Development of the male genital organs of *D. eugeniæ*.

(a) *External genitalia:*—In the larva, nine distinct sternites and tergites are visible, the future tenth and the eleventh segments not being marked clearly at this stage. The anus lies beneath the vasiform orifice and is protected by the lingula. In the first three larval instars, there is no indication of the genital appendages, and therefore, it is more or less impossible to differentiate externally between the male and the female. When the third instar larva becomes fully developed and is about to pupate, a male can be distinguished from a female by its smaller size, but even at this stage no trace of the genital appendages is present.

Just after pupation, there is a marked development of the appendages of the head and thorax, side by side with the development of the external genitalia. The common ejaculatory duct (Fig. 2, *r. d. ej.*) develops as a longitudinal slit running along the mid-ventral line of the ninth sternum, bordered by a pair of outgrowths (*r. ae. pr.*). These outgrowths are the rudiments of the external genitalia. The ectodermal cells bordering the slit are bigger than those elsewhere.

At a slightly later stage, each rudiment of the external genitalia (*r. ae. pr.*) tends to become doubled by the appearance of a horizontal longitudinal cleft, which begins from the posterior border and runs forwards for a short distance, so that the anterior part of each rudiment remains undivided. Thus two pairs of appendages (Fig. 3, *ae. l.*, *pr. l.*) are formed. Of these two pairs of genital appendages, the dorsal pair forms the rudiments

of the æedeagus (*ae. l.*), while the ventral pair is the rudiment of the parameres (*pr. l.*). At a still later stage of development, the rudiments of the æedeagus become fused to form a median tubular organ, bearing the gonopore at its apex. Even at this stage, the æedeagus and the parameres (Fig. 4) are continuous anteriorly. The separation of the æedeagus from the parameres takes place just before hatching of the pupa.

When the pupa becomes fully developed, all the eleven segments of the abdomen are clearly visible. The tenth and eleventh segments lack a sternum and are formed beneath the vasiform orifice. At this stage the greater part of the proximal portion of the genital appendages is enclosed within the ninth segment, which may, therefore, be called the genital segment in its true sense (as is found in the case of the adult Heteroptera).

(b) *Internal genitalia:*—In the larva the only portion of the internal genital organs developed are the testes, which lie between the sixth and the seventh abdominal segments laterally on either side of the alimentary canal. Each testis is surrounded by a thin sheath of connective tissue, and composed of a number of follicles which are filled with rounded cells with densely granular cytoplasm and well-marked nuclei. In the last larval instar, the posterior portion of each testis becomes a little constricted (Fig. 5, *v. d.*), the constriction being perhaps the origin of the vas deferens. Thus it may be concluded that in the last larval instar the vas deferens extends up to the seventh abdominal segment. The constricted portion of the testis consists of a single layer of endothelial cells surrounded by a thin connective tissue membrane, exactly similar to that of the testis.

After pupation, the testis becomes elongated and fill the sixth, seventh and eighth abdominal segments (Fig. 6). The peripheral follicles (Fig. 7, *t.*) contain large cells with comparatively small nuclei like those found in the testis of the larval instars, but the central follicles contain small cells which have comparatively large nuclei and stain more deeply with hæmatoxylin than do the nuclei of the peripheral follicles. The follicles on the inner surface of the testis contain bundles of spermatozoa and it is from this surface that the vas deferens (Figs. 6 and 8, *v. d.*) originates. The vasa deferentia are more or less transversely placed in the ninth abdominal segment. Histologically, the vasa deferentia consist of a single layer of more or less rectangular cells with large nuclei and a thin membranous covering of connective tissue. The testes and the vasa deferentia retain these features throughout pupal life, but just before hatching remarkable changes take place. The testes migrate forward from their original position and now come to lie in the fifth and sixth abdominal segments; as a result of this shifting forwards of the testes, the vasa deferentia are dragged forward and their posterior ends come to lie in the eighth abdominal segment, instead of in the ninth. The testes (Fig. 8, *t.*) become more or less rounded and more compact ; the portions of the vasa deferentia lying in the seventh and

eighth abdominal segments become very much dilated and come to have a wide lumen, thus forming the two vesiculæ seminales (*v. s.*). Posteriorly, the vesiculæ seminales join the paired ejaculatory ducts. There is no histological difference between the vesiculæ seminales and the vasa deferentia.

The common ejaculatory duct (Fig. 2, *r. d. ej.*) arises as an invagination of the ectoderm (*vide infra*) from the enlarged cells of the rudiments of the primary genital appendages (*r. ae. pr.*). It is an elongated structure extending up to the posterior margin of the ninth segment (Fig. 8, *d. ej.*). About the middle of the ninth segment, a pair of ejaculatory ducts (Figs. 8 and 9, *ej. d.*) originates from the common ejaculatory duct, one on either side; these are more or less transversely placed. At a slightly later stage, from the distal end of each paired ejaculatory duct originates an accessory gland, which is also therefore ectodermal in origin. Histologically, the common ejaculatory duct is formed of a single layer of columnar endothelial cells with an internal lining of chitin; the cells have distinct nuclei which stain deeply with hæmatoxylin; these cells are exactly similar to those of the genital appendages. In the proximal part of the ejaculatory duct, the endothelial wall is surrounded by a very thick muscular layer, which becomes very thin in the distal part. At the time of origin, the paired ejaculatory ducts are also formed of an endothelial layer of cells exactly like that of the common ejaculatory duct, but later on they develop a very thin covering of muscles and also a very thin chitinous lining. In the earlier stages, the structure of the accessory glands and their ducts is exactly similar to that of the paired ejaculatory ducts; the glands do not possess any muscular covering nor any chitinous lining, but later, the cells of the accessory glands become large and are surrounded by a thin covering of muscles, but no chitinous lining is developed in them at any stage. The structure of the ducts of the accessory glands remains as at the time of origin, except that they develop a very thin chitinous lining in them and are surrounded by a very thin covering of muscles.

In the early pupal stages, the vasa deferentia are not connected with the paired ejaculatory ducts. As growth proceeds, the common ejaculatory duct extends a little anteriorly, and the paired ejaculatory ducts also extend up to the middle of the eighth segment. The fusion of the vasa deferentia with the ejaculatory ducts takes place at the point where the accessory glands originate. Later, the accessory glands become very much elongated, and extend up to the fourth abdominal segment; their posterior ends remain constricted to form their ducts.

IV. DISCUSSION

A. *External genitalia*

The mode of development of genital appendages in Aleurodidæ is essentially almost similar to that found in other insects. These appendages

develop from a pair of ambulatory legs of the ninth segment. Palmen (1884) found that the ædeagus is paired in the adult Ephemeroptera, which is a very primitive group of insects, and therefore it is regarded that the ædeagus is a paired structure originally, which has become single by a fusion of paired elements secondarily in higher insects. Later on Verson and Bisson (1896) actually demonstrated the origin of the ædeagus in Lepidoptera by the fusion of a pair of appendages present at the earlier stage. Recently Singh-Pruthi (1924), George (1929), Metcalfe (1932), Mehta (1934), Qadri (1940) and others have conclusively shown in different orders of insects, that the ædeagus originates by the fusion of a pair of appendages present in earlier stages. Almost all workers now agree on this point.

As regards the origin of the parameres, I have already shown that in *D. eugeniæ*, they originate by the division of a pair of lobes. This is in conformity with the conclusions of other workers also, though some of them support this observation only indirectly. Singh-Pruthi (1925) describes the origin of parameres by the division of a pair of lobes—the 'paramere-lobes'—as termed by him. George (1929) says, "I regard the parameres not as distinct entities, but as processes of ædeagus, and as such the ædeagus is the representative of the endopodites of the appendages of the ninth segment." In fact the conclusions of Singh-Pruthi and George do not differ at all; only the former terms the original lobes, *i.e.*, the lobes from which the ædeagus and parameres are developed, as 'paramere-lobes', while the latter names the same structures as 'penis-lobes'. Thus both the structures are really identical in spite of having been named differently by them. Metcalfe (1932) and myself have also reached the same conclusion. In order to avoid a difference in nomenclature, I suggest that the original lobes may be called 'primary-lobes', each of which divide into two, the inner lobes of the two fusing to form the ædeagus, while the outer remaining distinct to form a pair of parameres.

That the genital appendages are modified ambulatory legs of the larva is accepted by all the recent workers. This view is also supported by my present study, and by the muscular attachment of these organs in the family Aleurodidæ (Rakshpal, 1940). But opinions differ regarding their homology. Most of the older workers regarded the ædeagus as having been formed by the fusion of two original endopodites. Escherich (1894) and Walker (1922) compared the parameres to the endopodites, but did not say any thing about the homology of the ædeagus. Kershaw and Muir (1922), however, having located the gonopore on the eighth segment, derived the subgenital plates from the appendages of the latter segment, and homologised the subgenital plates with the telopodites of the same segment. From their account we may conclude that they were under the impression that the parameres and the ædeagus represent the coxites and telopodites of the ninth

segment, because no mention was made by them about the absence of the coxites of this segment. Singh-Pruthi believes that the ædeagus and the parameres together represent the telopodites, while the subgenital plates represent the coxites of the ninth segment. George, not regarding the parameres as of any morphological importance, but only as outgrowths of the ædeagus, considers the subgenital plates as the coxites of the ninth segment. Thus George confirmed the view of Singh-Pruthi. Metcalfe (1932) is also in agreement with this view. I am also of the opinion that wherever the ædeagus and the parameres are present, they are homologous with the telopodites of the ninth segment, and that the subgenital plates represent the coxites of the ninth segment, and therefore, wherever as in the family Aleurodidæ, the subgenital plates are absent, the coxites are not developed. In my opinion, the absence of the subgenital plates is a secondary reduction. Thus we may conclude that the ædeagus, parameres and the subgenital plates are modified ambulatory legs of the ninth abdominal segment.

B. *Efferent ducts*

I have shown above that the vasa deferentia, being developed from the testes, are mesodermal in origin, and in the very early stages extend up to the seventh abdominal segment. The common ejaculatory duct, the paired ejaculatory ducts, and the accessory glands are ectodermal in origin. The gonopore, as in the males of the most insects, is situated posteriorly to the ninth segment. These observations are in conformity with those of most previous workers.

Weismann (1864) showed that all the genital ducts except the vasa deferentia are ectodermal in origin. Nussbaum (1882) found that in Blattidæ and Pediculidæ, the common ejaculatory duct, the accessory glands and the penis develop from the ectoderm, but no mention has been made by him about the paired ejaculatory ducts. Thus I agree with most of Nussbaum's observations. Amongst recent workers, my observations are in conformity with those of Singh-Pruthi (1925) and Metcalfe (1932), but George (1929) takes an entirely different view. He believes that except for the median posterior portion of the common ejaculatory duct, all other structures are mesodermal in origin. He is in agreement with some of the earlier workers, *e.g.*, Wheeler (1893), Verson and Bisson (1896), etc. Further, George maintains that a pair of ectodermal ejaculatory ducts do not exist at all and criticises the view of Singh-Pruthi in these words, "the vasa deferentia ending at the subgenital plate on the ninth segment, and the paired ejaculatory ducts extending forward almost up to the anterior limits of the eighth segment, and to meet each other a twisting is needed ; such a thing is not described by Singh-Pruthi". I believe George is mistaken because what he regards as the ampullæ of vasa deferentia are, in fact,

those of ejaculatory ducts, because the vasa deferentia do not extend up to the posterior margin of the ninth segment until the pupal stage is reached, while he describes these ampullæ even in the earlier nymphal instars. In *D. eugeniæ* also, the vasa deferentia extend up to the middle of the ninth segment, while the paired ejaculatory ducts originate from the common ejaculatory duct about the middle of the ninth segment, and extend up to the anterior limits of the ninth segment, and it is only at a little later stage that the fusion of the two takes place. Before their fusion the vasa deferentia are dragged forward so as to end about the middle of the eighth segment, while the ejaculatory ducts grow a little anteriorly and thus meet the vasa deferentia and make the fusion complete. Singh-Pruthi does not mention such a phenomenon in *Idiocerus*, but obviously from the position of the various components described by Singh-Pruthi, it is clear that such a phenomenon also takes place in *Idiocerus*. Thus in my view, George's criticism of Singh-Pruthi's view falls to the ground.

The common ejaculatory duct is more primitive than the paired ejaculatory ducts, firstly, because the origin of these ducts takes place when the common ejaculatory duct has already extended about the middle of the ninth segment. Secondly, the posterior portion of the common duct is not formed by the fusion of the paired ejaculatory ducts, as was believed by some older workers, *e.g.*, Nussbaum, but the paired ducts themselves originate from the common ejaculatory duct.

I have shown that the vasa deferentia extend up to the seventh abdominal segment in the very early stages; later they grow further and extend up to the middle of the ninth segment, but before fusion with the paired ejaculatory ducts they are dragged forwards and then fuse with them in the eighth abdominal segment. All these changes take place within a very short time. With regard to these points there has been a long controversy : Packard (1868), Korschelt and Heider (1899) hold that the vasa deferentia do not extend beyond the seventh abdominal segment ; Wheeler (1893) and George (1929) believe that they reach even beyond the ninth segment; while Korschelt and Heider (1899), Muir (1918), Singh-Pruthi (1925) and Metcalfe (1932) hold that there is a progressive shortening of the embryonic ducts and that later on they become connected with the paired ejaculatory ducts which are ectodermal in origin. My observations show that in very early stages, *i.e.*, in the third larval instar, the vasa deferentia extend up to the seventh abdominal segment, thus confirming Packard's, Korschelt's and Heider's views ; later on they extend up to the middle of the ninth segment, as postulated by Wheeler and George. As regards the third view, the fact is that the posterior end of each vas deferens does really travel forward ; whether due to the progressive shortening of the vasa deferentia or due to the vasa deferentia having been dragged anteriorly by the forward migration of the testes, it is not possible to decide at this stage, but it is

very probable that it is due to the latter reason. I may add that these different views have been put forward because all the stages were not studied.

The accessory glands originate from the anterior ends of the ejaculatory ducts ; thus they are also ectodermal in origin. Singh-Pruthi concludes that both the accessory glands and the paired ejaculatory ducts originate from the same elements, *i.e.*, paired hypodermal ducts. The paired hypodermal ducts, by a constriction in the horizontal plane along the whole length, become two pairs, a dorsal and a ventral, the dorsal forming the accessory glands and the ventral forming the paired ejaculatory ducts.

All the structures of the efferent system, except the commom ejaculatory duct, are paired in origin. This fact is in conformity with the observations of Singh-Pruthi and George. Metcalfe, however, believes that the efferent system, other than the testes and the vasa deferentia proper, is unpaired in origin, and that the common ejaculatory duct immediately divides to form two lateral ducts (paired ejaculatory ducts). I believe that the early origin of the paired ejaculatory ducts has influenced her in suggesting that they actually originate by the extension and division of the common ejaculatory duct; in fact both these ducts originate as paired outgrowths from the median ejaculatory duct. Thus the paired ejaculatory ducts are paired in origin and so are the accessory glands. The common ejaculatory duct arises from the ectodermal layer posteriorly to the ninth sternite, as shown by almost all previous workers,

As regards the situation of the gonopore of the male, almost all workers agree that it lies posteriorly to the ninth segment, except Kershaw and Muir, who locate the gonopore posteriorly to the eighth segment. But they are mistaken, because the formation of the gonopore takes place by the fusion of the endopodites of the ninth segment, as I have already shown.

V. ACKNOWLEDGMENTS

This work has been carried out under the direct guidance of Prof. K. N. Bahl, to whom I wish to express my deep gratitude for the great help and encouragement, and his painstaking correction of the manuscript. My thanks are also due to the University of Lucknow for the grant of research-fellowship for this work.

VI. SUMMARY

The genital appendages present in *D. eugeniæ* are the aedeagus and a pair of parameres. They develop from a pair of lobes representing the endopodites of the ambulatory legs of the ninth segment. The coxites of this segment are not developed, as a result of which the subgenital plates are absent. This primary pair of lobes subsequently divides into two pairs,

the inner pair fuse to form the ædeagus, while the outer remain free and form parameres. Thus the parameres are not simply outgrowths of the aedeagus as George believed, but develop really as separate morphological entities.

The vasa deferentia are mesodermal in origin. In the larva they extend up to the seventh abdominal segment. In the earlier stages of the pupa they extend up to the ninth segment, but are later dragged forward and extend only up to the eighth segment. The vesiculæ seminales are formed by the dilatations of the posterior portions of the vasa deferentia.

The paired ejaculatory ducts originate from the anterior end of the common ejaculatory duct. The accessory glands develop from the ends of the paired ejaculatory ducts. The commom ejaculatory duct is formed by an invagination of the ectodermal cells of the primary pair of the genital appendages. The gonopore is situated behind the ninth segment.

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STUDIES ON INDIAN COPEOGNATHA (PSOCOPTERA)

I. INTRODUCTION, GENERAL MORPHOLOGY AND CLASSIFICATION*

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(*Received for publication on 5th March*, 1941)

I. INTRODUCTION

The Copeognatha or Psocoptera, popularly known as psocids, book-lice, wood-lice, etc., are small, delicate insects. On account of their insignificant size and being practically of little economic importance this group of insects has received scanty attention from entomologists.

The order was given the name *Copeognatha* (*kopeus* : chisel, *gnathos*: jaw) by Enderlein (1903a), because the members of this order invariably possess a pair of chisel-shaped appendages associated with their mouth-parts. Earlier entomologists had designated this group Psocoptera (*psocus*: porpoise, *pterov*: wing), because, most of these insects hold their wings roof-wise over the abdomen while at rest, and, in that posture they resemble miniature porpoises. Some have assigned the name *Psocida* to this group (Imms, 1930) and placed it as a suborder of Psocoptera with the Zoraptera as another suborder. The name Psocoptera, however, is not quite appropriate for the order, since in some genera the wings, at rest, are held one over the other, parallel to the dorsal body-surface, as is the case in Embioptera and Isoptera; further, some genera are wholly apterous. Hence the alternative name Copeognatha, seems preferable. The name psocids, derived from the genus, *Psocus*, on which the order is based, is often used for this group in this paper.

Literature on the systematics of the Copeognatha is very much scattered. The few papers published before 1900 are mostly by Hagen, MacLachlan and Kolbe. From the beginning of the present century, however, the psocid fauna has received better attention and a good number of species have been recorded by different investigators from various parts of the world. The largest amount of work is due to Enderlein, whose valuable contributions amount to seventy-two papers, describing species from almost all parts of the world. Among the publications of this author, special mention may be made of "The Monograph of the Indo-Australian Copeognatha" (1903), "Monograph on the scaly-winged Copeognatha" (1906) and "The fossil Copeognatha and their phylogeny" (1911). Among

*The work embodied in these contributions was conducted in the Biology Laboratory of the Wilson College, Bombay.

other workers, Banks, Navas, Pearman, Badonnel, Ball, Chapman, Okamoto, Tillyard, Ribaga, Reuter and Hickman deserve special mention.

The psocid fauna of India is yet only very little investigated; so far, only thirty-three species have been recorded from this country. These were described by various investigators, like, MacLachlan (1872 and 1873), Kolbe (1883), Enderlein (1903), Needham (1909), Banks (1914), and Navas (1934). On the suggestion of Dr. C. J. George, Wilson College, Bombay, a study of this order was undertaken by the writer and through his limited search, he was able, during the past seven years, to discover forty-five additional species, which are recorded in this contribution. A preliminary report on two new species has already been published (Menon, 1938a).

II. Material and Methods

The material for the present studies was collected by the writer during the years 1934-38 mostly from Bombay and its environs and a few localities in Cochin State (South India) during the time of his fellowship in Wilson College, Bombay. They were mostly procured from heaps of dry fallen leaves. Some were collected at light. Three species were obtained in large numbers from stored rice, pulses,etc., during the monsoon months—June to October. One species was found breeding inside crevices on the walls, while another was found commonly under web on the lower surface of green mango leaves.

Proper specific indentifications were possible only after a thorough investigation of their morphological details, especially of the mouth-parts and genitalia. These could be studied well only after dissection. Balsam preparations were not quite satisfactory and the following method, kindly suggested by Pearman, had largely to be employed. The head, antennæ, wings, thorax and abdomen were first separated from one another under a binocular-microscope. The antennæ and wings were transferred directly to the clearing medium, "chloral-phenol", which is a mixture of equal parts of chloral hydrate and phenol crystals melted together without the addition of water. In about five minutes the various parts get cleared in this medium. From this they were removed to a mixture of equal volumes of chloral-phenol and the mounting medium "gum-chloral". After keeping them in this mixture for a few minutes, they were transferred to pure gum-chloral, composed of :

Distilled water	.. :	2.0	parts by volume
Gum arabic	.. :	1.0	,,
Chloral hydrate	.. :	2.0	,,
Glycerine	.. :	0.25	,,

For the sake of proper orientation a thin layer of the mounting medium was first spread on a clean slide and the dissected parts arranged in the

desired position. The slide at this stage was kept aside for some time, well protected from dust. When it was found partially set, a fresh layer of the mounting medium was spread over it and the cover-glass placed in position. The head, thorax and abdomen were first treated with cold strong solution of caustic potash for about half an hour. These parts were then rinsed in alcohol and kept in distilled water for some time. Then they were treated as for antennæ and wings. The head and abdomen were further dissected in the mounting medium so as to expose the mouth-parts and genitalia.

III. General morphology

The Copeognatha, though a group of generalised insects, show in their general morphology certain features seldom met with in other insects. The most peculiar of these is the pair of chisel-shaped appendages already referred to, called the maxillary 'picks'. Among other characteristic features mention may be made of (i) the tumid clypeus which forms a conspicuous part of the head capsule, (ii) the peculiar alinotal divisions, with two pairs of crests, the *cristæ scutelli*, (iii) the characteristic venation, to which the Psyllidæ (Homoptera) alone show the nearest approach, and (iv) the unique tarsal combs or *ctenidia*.

The head (Figs. 1 and 2) is typically hypognathous and the various cranial areas can readily be distinguished. The epicranium (*ep*) is comparatively large and a Y-shaped suture, composed of a median (*ms*) and two lateral sutures (*fs*), separates it from the frons and divides it into two lateral halves. The arms of this suture may be partly or wholly indistinguishable. The clypeus (*cl*) is large and occupies a good portion of the head capsule as noted above. Below this is a short transverse piece, the anteclypeus, (*ancl*) with which the labrum (*lbr*) articulates. The sides of the head are formed by the genæ (*g*). The eyes (*e*) are usually well developed, with several facets and situated towards the postero-lateral angles of the head. Rarely, as in *Liposcellis*, they are reduced and composed of only few ommatidia. The cornea, sometimes, bears hairs between the facets. It is noteworthy that in *Peritroctes* these hairs form short combs. Usually, there are three ocelli (*oc*) situated in the form of a triangle. A correlation between the presence of ocelli and wings is often met with, the apterous and the brachypterous forms being usually devoid of these organs. Rarely, as in *Tineomorpha*, *Cymatopsocus* and *Nephax*, only two ocelli are present and these are situated just in front of the compound eyes. The antennæ are fairly long and conspicuous, composed of from thirteen to over forty segments. Of these, the two basal segments, the scape (*scp*) and the pedicel (*ped*) are generally stouter than the remaining segments, which form the flagellum (*fl*). The flagellar segments are usually hairy and those

of the males are usually more pubescent. Sometimes the flagellar segments are secondarily annulated.

The mouth parts are of the orthopteroid type. The labrum (*lbr*) is a more or less subrectangular piece articulating with the anteclypeus (*ancl*). The mandibles (Fig. 5) are hard and well chitinised, with an anterior cutting edge (*c*) and a posterior molar area (*ma*). They present a distinct asymmetry, the teeth of the one fitting into the clefts of the other and also the molar area of the right mandible being posteriorly beaked. The shape of the mandibles appears to be characteristic for the various families. The maxillæ are of special interest because associated with these are found the maxillary-picks (Fig. 7) referred to above. The 'picks', regarded by some authorities as homologous with the laciniæ of the generalised insect, are long and well chitinised structures. They vary in shape in the different groups and thus afford valuable taxonomic characters. The galeæ are lightly chitinised, flattened, sub-cylindrical and somewhat twisted structures enveloping the maxillary-picks. The 'picks' are capable of being extruded and retracted through a groove in the galeæ by sets of muscles attached to their bases. The maxillary palpi (Fig. 6) are four-jointed, with the first and third segments short, and the second and fourth segments long. The segments are usually hairy; besides, they may bear spurs (*sp*) also, the number and arrangement of which are valuable in diagnosing various species. The labium (Fig. 4) is little specialised; but its palpi (*lbp*) are reduced, with usually one, or at the most two segments.

The thorax (Fig. 2) is characteristically specialised. The pronotum is generally small, poorly developed and not visible from the dorsal aspect, being telescoped in between the vertex of the head and the anterior lobe of the mesonotum. The alinota are usually well developed and structurally quite unique. Each sclerite is divisible into four main regions, an anterior, antedorsum (ad_1 and ad_2), followed posteriorly by the dorsum (d_1 and d_2), postdorsum (pd_1 and pd_2) and scutellum (sc_1 and sc_2) respectively. The dorsum bears a median suture so that it is divisible into two lateral areas. The scutellum is somewhat wedged into the postdorsum so that this is also separable into two lateral halves. The scutellum, further, bears two pairs of narrow crests laterally (crs_1 and crs_2) called the 'cristæ scutelli' already referred to. It is noteworthy that the anal margins of the wings lie closely approximated to the anterior pair of these crests, when not in use. The alinota are, however, rarely undivided as in *Liposcellis*, *Psacadium*, etc. The thoracic sterna are usually much reduced; but in the Liposcellidæ they are well developed and their shape and chaetotaxy are very valuable for determining the species.

The Copeognatha are primarily winged insects, though some species have lost these organs. The wings, when present, are usually membranous, pigmented or unpigmented, and with or without hairs or

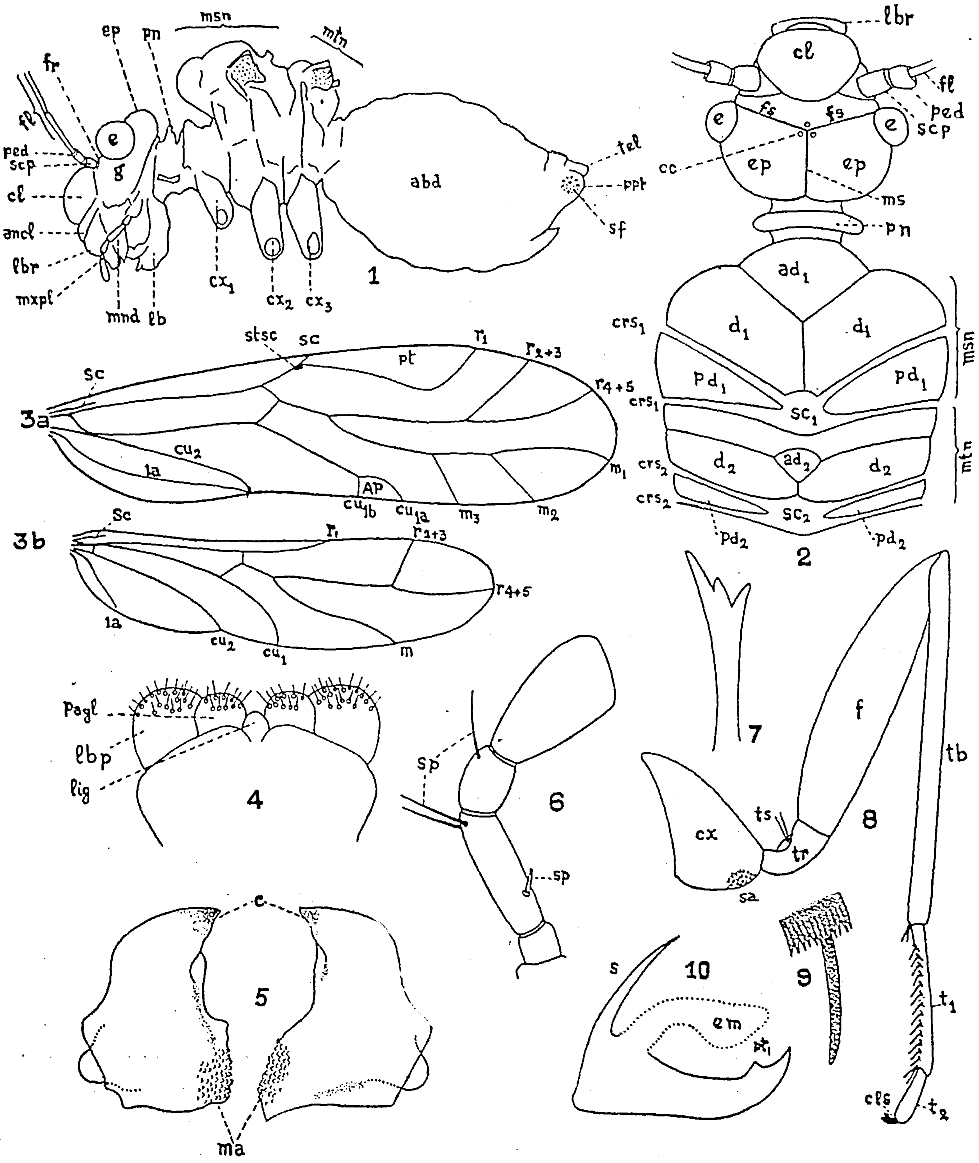

FIG. 1 *Stenopsocus stigmaticus* Imh. et Labr. Lateral view (After Badonnel). FIG. 2 *Psocus* sp Plan of the dorsal view of head and thorax (After Enderlein). FIG. 3 *Cæcilius* sp. Venation. *a*, forewing; *b*, hindwing. FIG. 4 *Pseudocæcilius* sp. Labium. FIG. 5 *Cæcilius* sp. Mandibles. FIG. 6 *Lepolepis* sp. Maxillary palp. FIG. 7 *Liposcellis* sp. Maxillary 'pick'. FIG. 8 *Cæcilius* sp. Hind leg. FIG. 9 *Cæcilius* sp. A ctenidium. FIG. 10 *Hemipsocus* sp. A claw.

1a, anal vein; *abd*, abdomen; ad_1, ad_2, antedorsum; *ancl*, anteclypeus; *ap*, areola postica; *c*, cutting edges of mandibles; *cl*, clypeus; *cls*, claws; crs_1, crs_2, cristæ scutelli; cu_1, cu_2, cu_{1a}, cu_{1b}, branches of cubitus; *cx*, cx_1, cx_2, cx_3, coxæ; d_1, d_2, dorsum; *e*, eye; *em*, empodium; *ep*, epicranium; *f*, femur; *fl*, flagellum; *fr*, frons; *fs*, frontal sutures; *g*, gena; *lb*, labium; *lbp*, labial palp; *lbr*, labrum; *lig*, ligula; *m*, m_1, m_2, m_3, branches of media; *ma*, molar areas of mandibles; *mnd*, mandible; *ms*, median suture; *msn*, mesonotum; *mtn*, metanotum; *mxpl*, maxillary palp; *oc*, ocelli; *pagl*, paraglossa; pd_1, pd_2, postdorsum; *ped*, pedicel; *pn*, pronotum; *ppt*, paraproct; *pt*, pterostigma; pt_1, pre-apical tooth of claw; r_1, r_{2+3}, r_{4+5}, branches of radius; *s*, basal hair of claw; *sa*, stridulatory area; *sc*, subcosta; *scp*, scape; *sf*, sense field; *sp*, spurs; *stsc*, stigmasac; t_1, t_2, tarsi; *tb*, tibia; *tel*, telson; *tr*, trochanter; *ts*, trochanteral setæ.

scales. The venation, nature and extent of pigmentation and chaetotaxy are very valuable in distinguishing the various species. The hindwings are invariably smaller and have reduced venation. In some genera, e.g., *Atropos, Lepinotus, Echinopsocus*, etc., the wings are reduced to mere flaps. *Psyllipsocus, Archipsocus, Psoquilla, Psocatropos*, etc., present varying grades of wing development within the same species. *Embidopsocus, Psacadium* and *Peritrocles* exhibit an alary dimorphism wherein some forms bear fully developed wings while others of the same species are totally apterous. *Sphaeropsocus* is peculiar in that it has only the anterior pair of wings and these are well-chitinised, resembling the elytra of beetles and have a peculiar venation.

The normal venation of the forewings (Fig. 3a) may be briefly described as follows. The costa is wanting as a distinct vein. The subcosta (*sc*) is broken up into two segments, a basal and a distal one, of which the basal one soon fades into the wing membrane. The distal one emerges from the first branch of the radius (r_1) and forms the basal boundary of the pterostigma (*pt*). About the level from where the distal part of *sc* arises, a stump of a vein projects from the inner surface of the wings ; this is termed the 'stigma-sac' (*stsc*). The first branch of the radius (r_1) is long and wavy and forms the basal and distal boundaries of the pterostigma. The radial sector (*rs*) takes its origin from the radius at about the middle of the wing and is forked to form the veins r_{2+3}, and r_{4+5}. The media and the radius take their origin together, but close to the wing-base the former separates, descends and fuses with the first branch of the cubitus (cu_1). This fusion continues up to the level of the origin of *rs* where these veins diverge sharply from one another. The media then fuses with *rs* for a short distance and then it becomes free again and terminates in three branches, m_1, m_2, and m_3. The first branch of the cubitus (cu_1), just before reaching the wing margin, forks into two branches; the basal branch (cu_{1b}) is short, but the distal one (cu_{1a}) is fairly long and forms a well-marked cubital loop, which encloses the area called the 'areola postica' (*ap*). The clavus or anal area is separated from the rest of the wing by the second branch of the cubital vein (cu_2) which leaves the main stem of the cubitus so close to the wing-base that it was considered for a very long time as the first anal vein, until Tillyard (1923) showed its exact nature. There is usually only a single anal vein (1*a*), which is arched and runs nearer to the wing-margin and terminates together with the tip of cu_2 forming a nodulus.

The forewing venation of other psocids presents some variations from that given above. These may be briefly described. In some genera (*e.g., Scoliopsyllopsis*) *sc* is present as a distinct vein throughout its course. In *Neurostigma* a series of veinlets start from r_1 and reach up to the costal margin. In some genera (*e.g., Stenopsocus*) r_1 is connected with *rs* by a cross-vein ; in some, (*e.g. Amphipsocus*), this cross-vein is incomplete and

does not reach *rs*. Rarely *rs* is divided into more than two branches (*e.g. Harpezoneura*). The veins, *rs* and *m* , may be fused over a stretch, or these veins may meet at a point (*e.g. Ectopsocus*). In the family Thrysophoridæ r_{4+5} is also connected or fused with *m*. The media is usually three-branched, but rarely it is only forked once (*e.g. Mepleres*) and in some cases there are more than two branches for this vein (*e.g. Neurostigma*). Sometimes *m* is fused with the vertex of the areola postica (*e.g. Psocus*) or connected with it by a cross vein (*e.g. Stenopsocus*). Rarely (*e.g. Ectopsocus*) the areola postica is wanting, cu_1 being unbranched. Usually cu_2 and 1*a* end together in a nodulus, but in the Atropetæ and the Nanopsocetæ these veins have separate endings on the wing-margin. Generally only a single anal vein is present, but, in some scaly psocids (*e.g. Stimulopalpus*) two anal veins are present. As has been pointed out, *Sphaeropsocus* has a peculiar venation. In *Calopsocus, Neurosema* and *Dictyopsocus* the venation is partly reticulate. In *Embidopsocus* and *Semnopsocus* only two longitudinally-running, indistinctly-demarcated veins are present.

In the hindwing, the venation (Fig. 3b) is considerably reduced. The subcosta (*sc*) is a mere remnant and there is neither a pterostigma nor a 'stigma-sac'. Though the radial sector is forked as in forewing, the media (*m*) and the first branch of the cubitus (cu_1) are both simple. The radius, media and the first branch of the cubitus arise together ; these veins are basally fused for a short distance, and distally, about the middle of the wing, the radial sector and media are again fused over a short stretch. The cubital loop and the 'areola postica' are wanting. The anal vein (1*a*) is short and ends far behind the second branch of the cubitus. (cu_2).

The hindwing venation does not present so much variations as does that of the forewing. Yet, the following are worthy of note. In *Tapinella*, r_1 is entirely suppressed. In *Archipsocus*, *rs* and its branches are wanting. In some genera (*e.g. Empheriella, Tineomorpha,* etc.) the media is forked. The veins *rs* and *m* may be fused over a stretch, or they may meet at a point, or these veins may be connected by a cross-vein (*e.g. Ectopsocus*). In some genera (*e.g. Tapinella, Thylacopsis, Empheriella,* etc.) *r*, *m* and cu_1 are fused together to form a stem-vein, from which their distal parts start off.

The legs (Fig. 8) show little specialisation. The coxæ (*cx*) are normally broad and appressed towards the sterna. They are, however, longer and narrower in *Liposcellis* and allied genera, in which the sterna are well developed. A peculiar meso-coxal interlocking arrangement (Menon, 1938), wherein the left meso-coxa bears a condyle-like protuberance, which fits exactly in a cup-shaped concavity on the right meso-coxa is present in *Udamolepis*, *Psocatropos*, etc. The hind-coxæ usually bear stridulatory organs (*sa*), consisting of denticulated areas, on their inner surfaces. The trochanters (*tr*) are fairly long and their distal margins are completely anchylosed with the basal margins of the femora. On the outer side of each trochanter

is a pair of setæ (*ts*) situated in a depression, designated 'trochanteral setæ' in this paper. The femora (*f*) are usually long and subcylindrical, though in *Liposcellis*, they are broader and flattened, the hind femora more so. The tibiæ (*tb*) are little specialised. The tarsi (t_1, t_2) may be two- or three-jointed. The first tarsal segment of the hind-leg usually bears a row of appendages called 'ctenidia'. Each ctenidium (Fig. 9) is more or less a scale formed by the fusion of a row of hairs, of which one about the middle is developed into a seta. The last tarsal segment bears a pair of claws (*cls*). Each claw (Fig. 10) may bear a basal hair (*s*) and an expansible empodium (*em*), which is practically invisible in balsam preparations. On the inner surface, the claws may bear additional teeth (pt_1).

The abdomen (Fig. 1, *abd*) is usually somewhat fusiform and composed of ten segments. In *Liposcellis* and allied genera it is somewhat compressed dorsoventrally, with partial or even complete fusion of the ninth and tenth segments. The last segment bears a median triangular flap (*tel*), the telson or epiproct and a pair of subtriangular sclerites (*ppt*) on either side of the telson, called the paraprocts. The paraprocts each bear a dorso-lateral 'sense-field' (*sf*), on which are borne a varying number of peculiar sensory hairs called 'trichobothria'. This sense-field appears to be homologous with the cerci of the generalised insect. In some genera the tip of each paraproct bears an inwardly-directed spine termed the 'appendix analis'. In some genera the paraprocts may be modified and bear accessory chitinised processes or hooks (*e.g. Hemipsocus*), while in others the last abdominal segment and telson also may bear such appendages.

The genitalia have recently been found to be very valuable in the taxonomic study of psocids. The female genitalia usually consists of three pairs of valves, one borne by the eighth segment, and two, an outer and an inner pair, borne by the ninth segment. Varying grades in the reduction of these valves are met with in the various families. Typically the valves of the eighth segment are long, narrow and slightly chitinised. The inner valves of the ninth segment resemble those of the eighth, but are relatively broader. The outer valves of the ninth segment are broad, heavily chitinised and usually bear a number of bristles. The female genitalia are usually concealed from view by the subgenital plate, which is the posteriorly-produced seventh sternite. The variation in shape, patterns of markings and chaetotaxy exhibited by the subgenital plate are of considerable taxonomic value. In some genera the subgenital plate is posteriorly produced into a short prolongation, which forms the 'egg-guide'.

The male genitalia consists of a median ædeagus and the associated chitinised parts, which together form the 'hypandrium' and a pair of parameres, which may be fused together to form a more or less collar-like 'phallic sclerite'.

The nature and arrangement of hairs on various parts of the body (chaetotaxy) are of taxonomic value. The hairy outgrowths are primarily of two kinds. Short, fine, cuticular processes, the *microtrichia*, and long processes, set in distinct basal alveoli, the *macrotrichia*. In this paper the term 'hair' refers only to the latter. The hairs may be long and curved, when they are said to be 'shaggy'. When they are long and more or less straight, they are called 'bristles'. When the bristles are stout, they are termed 'setæ' or 'spurs'. In some genera, setæ with minute lateral processes along their length have been noted. Scale-like hairs have been noted in *Psocatropos*. Hairs with truncate tips are met with in *Liposcellis*. Glandular hairs have been noted in the nymphs of certain genera. Scales of different shapes are borne by the Amphientomidæ and Lepidopsocidæ.

IV. Classification

Various schemes for classifying the Copeognatha have been proposed by different taxonomists at various times, based on different morphological characters. The schemes differ so much one from another that none of them has been widely accepted. Kolbe (1880) was the first to propose a classification of psocids. He considered the psocids as a single family, the Psocidæ, under the order Neuroptera. He divided this family into several tribes, basing his divisions entirely on the nature of the wing-venation. Enderlein's studies made him believe that the number of tarsal segments was of primary importance, and he (1911) accordingly grouped the psocids under two suborders, Isotecnomera (psocids with two-jointed tarsi) and Heterotecnomera (psocids with three-jointed tarsi). For the separation of the various families, he took into consideration the nature of the antennæ, maxillary palpi, prothorax and venation. He thus proposed an elaborate scheme of taxonomy and even traced the probable affinities of genera. Tillyard's studies led him to conclude that the correct dichotomy of the order could not be based on the number of tarsal segments, but must be based on the nature of the cubital forks of the forewings. He (1926), therefore, regrouped Enderlein's various families (represented in Australia and New Zealand only) under two different suborders Parapsocida and Eupsocida. In the former cu_2 and $1a$ have separate endings on the wing margin and the branches of cu_1 run straight, there being no cubital loop, whereas in the latter cu_2 and $1a$ end together in a nodulus and the first branch of cu_1 forms a distinct loop. He also revealed two more suborders (fossil) from the Permian strata, the Permopsocida and the Embiopsocida (Tillyard, 1928). Banks also did not attach much importance to tarsal structure. In the scheme proposed by him (Banks, 1929), he took into consideration primarily the nature of the areola postica and pterostigma, and, as additional characters, the presence of scales and the nature of the prothorax. He regarded psocids only as a superfamily, Psocoidea, of the order Corrodentia. As

such, he did not group his families into major divisions. Karny (1930), in his elaborate scheme of classification, based mainly on the nature of the venation, accepted Tillyard's subordinate ranks, but placed the two hundred and thirty-four then-known genera under eleven families, different from either those of Enderlein or Banks. He further separated thirty subfamilies and twenty-three tribes. Pearman (1936) proposed an entirely different scheme, taking into consideration the external anatomy of the various genera as a whole. According to him, the skeletal organs occur in a comparatively limited number of distinctive forms (types) and that these type-forms are segregated in certain definitive correlations. These insects thus classify themselves, the general traits of the correlated parts characterising the major groups and particular modifications of the structural type-forms distinguishing minor groups. He thus separated eight major groups and assigned to each of them a status somewhat superior to that of a superfamily. Further, he suggested, as a provisional measure, to place such genera as *Allopsocus*, *Psilopsocus*, etc., whose structural details are at present not known, under an additional group, 'Psocida agnota.' He separated different families also under these groups. In the preliminary sketch published by him no attempt was, however, made to give the diagnostic characters of the various groups or families; instead, well-known genera were designated to typify each of these morphological segregations.

The classification followed in this contribution is based upon Pearman's scheme. A key for identifying the various major groups based on this scheme is given below. Detailed diagnostic descriptions of the groups and other subdivisions will be given along with those of different species.

Key to the major groups

1. Maxillary 'picks' subcylindrical, apically produced into distinct tines; labial palpi distinctly two-jointed; antennæ with more than 13 segments .. .. 2.

   Maxillary 'picks' subcylindrical, without distinct apical tines or somewhat shovel-shaped; labial palpi unjointed or when two-jointed, the two segments together forming a composite circular plate; antennæ with 13 segments .. .. .. 4.

2. End-segment of the maxillary palpi elongate-oval or subglobular; wings well developed or totally wanting; wings when present held parallel to the dorsal body-surface while at rest; antennæ 15- jointed .. .. *Nanopsocetæ.*

   End-segment of the maxillary palpi hatchet-shaped; wings well developed or reduced, but never totally apterous; wings held roof-wise over the abdomen while at rest; antennæ with more than 15 segments .. .. 3.

3. Female genitalia composed of only two pairs of valves; cu_2 and $1a$ of fore-wings ending together in a nodulus .. .. *Psocatropetæ.*

   Female genitalia composed of only a single pair of valves; cu_2 and $1a$ of fore-wings having separate endings on the wing-margin .. .. .. *Atropetæ.*

4. Scaly forms; labial palpi two-jointed, the two joints together forming a composite circular plate .. *Amphientometæ.*

   Scale-less forms; labial palpi unjointed .. .. 5.

5. Mandibles much longer than broad; labial palpi with truncate anterior margin .. .. .. 6.

   Mandibles as broad as long or broader; labial palpi with rounded anterior margin .. .. 7.

6. *Rs* and *m* of fore-wings widely apart, connected by a distinct cross-vein; claws with a pre-apical tooth; outer valves of the ninth sternite of female bearing a number of bristles .. .. .. *Epipsocetæ.*

   Rs and *m* of fore-wings lying nearer together and fused over a stretch; claws without pre-apical tooth; outer valves of the ninth sternite of the female without any bristles or at the most bearing only two .. .. *Cæciliatæ.*

7. Maxillary 'picks' more or less shovel-shaped; areola postica free or connected with *m* by a moderately long cross-vein .. .. *Homilopsocida.*

   Maxillary 'picks' subcylindrical, apically stouter and more or less truncate, with flattened teeth; areola postica fused with *m* or connected with it by a very short cross-vein .. .. .. *Pscocetæ.*

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STUDIES ON INDIAN PARASITIC HYMENOPTERA—I*

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This is an account of my recent studies on some of the parasitic Hymenoptera, received by the Imperial Entomologist, New Delhi, for identification from different parts of India. The type specimens of the ten new species described here are deposited in the Imperial Pusa Collection, Laboratory of the Imperial Entomologist, Imperial Agricultural Research Institute, New Delhi.

Superfamily CYNIPOIDEA

Family *FIGITIDÆ*

Subfamily EUCOILINAE

Hypolethria ramachandrai, sp. nov.

Female.—About 2.0 mm. long. Shiny dark reddish-brown. Body strongly compressed. Head black, sparsely hairy; viewed in front almost round; cheek about half the length of orbit; eye pubescent; occiput more densely hairy than the rest of head. Scape, pedicel and funicle honey-brown; club dark brown; the whole antenna moderately clothed with white hairs; third antennal segment one and a half times the second, fourth to sixth segments shorter, subequal to each other, seventh segment stouter and somewhat longer, eighth segment stouter and longer than seventh, the rest forming the club; club segments ovate, longer than the funicular segments. Pro- and mesonota reddish-brown, shiny, not sculptured, with a few scattered hairs. Scutellum darker, more densely hairy, the central elevation oval with its surface smooth and shiny, rest of scutellum reticulately sculptured. Pleura honey-brown. Legs brown or honey-yellow, terminal tarsal segments black. Abdomen dark reddish-brown above and lighter below, ringlet of hairs at base very prominent. Veins brown.

Male.—Very similar to female, except in the usual secondary sexual characters. Fourth antennal segment is the longest.

Holotype one female, allotype one male and paratype one female, mounted on one slide, received from T. V. Ramakrishna Ayyar, Coimbatore and labelled: "Parasitic in pupæ of a small black fly breeding in *cholam* dead-heart, Coimbatore, Y. Ramachandra Rao collection, 26-iii-1915." I have also before me a few specimens of this species, received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled: "Cynipid

* For other similar papers by the same author see *Rec. Indian Mus.*, for 1934-38 and *Indian J. Ent.*, 1939.

hyperparasite of a small black Diptera breeding in decaying tunnels of *Sesamia uniformis* in sugarcane, Sagauli (Bihar), 10-iv-1939; P.C.S. No. 299, from stem-borer tunnels in sugarcane, Lakshmanan collection, 30-v-1939."

Superfamily SERPHOIDEA

Family *SCELIONIDÆ*

Subfamily TELENOMINAE

Telenomus saccharicola, sp. nov.

Female.—About 1.0 mm. long. Black. Head viewed from above slightly wider than thorax, thin fronto-occipitally, eyes pubescent, ocellocular space slightly greater than the diameter of the ocellus; head viewed in front a little less than twice as broad as long, face longitudinally striated, striæ converging to the mouth; cheek equal to the length of eye, smooth, shiny and with a strong carina from eye to mouth. Scape at base and apex dark reddish-brown, club black, about 7/8 the length of scape; first funicular segment about two-thirds the length of pedicel, second about three-fourths the first, third segment somewhat shorter than second, fourth about half the length of the first; second and third club segments subequal, terminal club segment one and one-fourth the penultimate club segment.

Thorax very closely and minutely punctate, coxæ and femora, except knees, black. Knees, tibiæ and tarsi reddish-brown. Second tergite of abdomen nearly as long as broad, covered practically for its entire length with very fine diverging, longitudinal striæ.

Holotype one female and paratype one female on a strip of celluloid on pin, with one antenna of the paratype mounted on a slide. Received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled: "C. S. No. 177, parasitic in the eggs of a pentatomid bug (?) on sugarcane leaf, New Delhi, M. Ahmad collection, 10-viii-1937."

This species is easily distinguished from *Telenomus anwari* Mani[1] by its wider head, striated face, the relatively longer striations on the second abdominal tergite and different proportions of the antennal segments.

Family *CALLICERATIDÆ*

Subfamily MEGASPILINAE

Lygocerus rufipes (Thomson)

1858. *Ceraphron rufipes*, Thomson, *Öfv. Kongl. Vet.-Akad. Förhand.*, **15**: 293.
1898. *Lygocerus rufipes*, Dalla Torre, *Cat. Hymen.*, **5**: 534.
1914. *Lygocerus rufipes*, Kieffer, *Das Tierreich*, **42**: 153.

I refer to this species (Fig. 1) four female specimens received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled: "P. C. S.

[1]MANI, 1939, *Indian J. Ent.*, **1** (1-2): 94.

No. 247, from cocoons of a chrysopid on sugarcane, Jullunder, Iswar Dyal collection, 29-iii-1939."

The species was originally described from Sweden and is being recorded here for the first time from India.

The specimens before me have the antennal scape coloured dark brown at base and black otherwise. The specimens are also somewhat larger, *viz.*, 2.0 mm., but otherwise agree with Kieffer's description of the species.

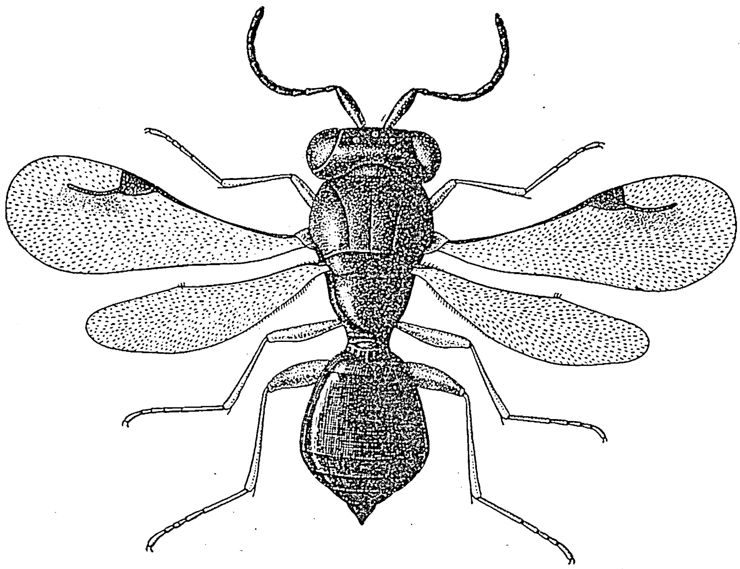

FIG. 1. *Lygocerus rufipes* (Thomson), female.

Superfamily CHALCIDOIDEA
Family *EURYTOMIDÆ*
Bephratoides saccharicola, sp. nov.

Female.—4.5 long. Black. Head black, covered with long, silvery-white pubescence; viewed from above broader than thorax, its length to width in the ratio of 5 : 6; viewed in front length to width in the ratio of 13 : 15; interocellar space one and a half times the ocellocular; front ocellus distinctly above and outside of the scrobes; vertex distinctly impressed laterad of the posterior ocelli and densely covered by flat-umbilicate, setigerous punctures; face very distinctly carinate round the eyes, not concave, with a prominent median carina running to the mouth from the insertion of the antennæ and two sublateral carinæ converging forwards from the anterolateral borders of the scrobes; face below antennæ with converging

striæ; malar space sparsely punctate, shorter than eyes; scrobes deep, shiny and smooth.

Antennæ : scape, pedicel and ring-joint brown, flagellum dark brown ; first funicular segment longest and little over three-fourths the scape, second to the fifth segments subequal, sixth three-fourths the fifth, club solid and equal to fifth funicular segment.

Thorax wholly black, moderately densely clothed with silvery-white pubescence and flat-umbilicate, setigerous punctures. Propodeum concave mesad. Veins pale brown ; marginal and postmarginal veins subequal, the former not unusually thick, its thickness never exceeding one-sixth the length ; stigmal vein a little over half the postmarginal vein. All coxæ black, femora reddish-brown, fore and mid-tibiæ and tarsi brown, hind tibiæ dark brown in the basal half and light brown in the apical half with two apical spurs, hind tarsi light brown. Abdomen usual.

Holotype one female, paratypes three females on pin, received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled : "C. S. No. 241, parasite in cocoons in tunnels of *Scirpophaga nivella* in sugarcane, Pusa (Bihar), Ejaz Hasan collection, 20-viii-1938."

Family *ENCYRTIDÆ*

Subfamily ENCYRTINAE

Litomastix daccaensis, sp. nov.

Female.—0.8 - 0.9 mm. long. Black with dark green or dark coppery reflections on mesoscutum and scutellum. Head brownish-black, finely shagreened ; viewed from above as wide as its median length, somewhat wider than thorax, occipital margin sharp ; interocellar space about thrice the ocellocular ; viewed in front as in figure 2 a ; pubescence brown.

Antennæ (Fig. 2 b) very dark brown, shorter than body, with dense gray pubescence ; scape equal to funicle, pedicel about half the length the scape, all segments of funicle subequal to each other ; club solid, nearly equal to five funicular segments combined, broadly and obliquely truncated at apex.

Thorax shagreened, with dark metallic sheen on mesoscutum and coppery sheen on scutellum. Wings hyaline ; marginal vein of fore wings subequal to stigmal, postmarginal somewhat shorter than marginal ; marginal ciliation as in figure 2 c.

Legs : fore femora dark brown ; middle and hind femora brownish-black ; tibiæ brown, with dense white pubescence ; tarsi brown, hind metatarsus somewhat shorter than the following two segments combined.

Abdomen about equal to thorax.

Holotype one female dissected on a slide, paratypes numerous female specimens in spirit, received from the Jute Specialist, Tejgaon, Dacca, labelled : "No. 6, parasite of jute semilooper, *Cosmophila sabulifera,* Dacca farm, Gopi Mohan Das collection, 28-vii-1940."

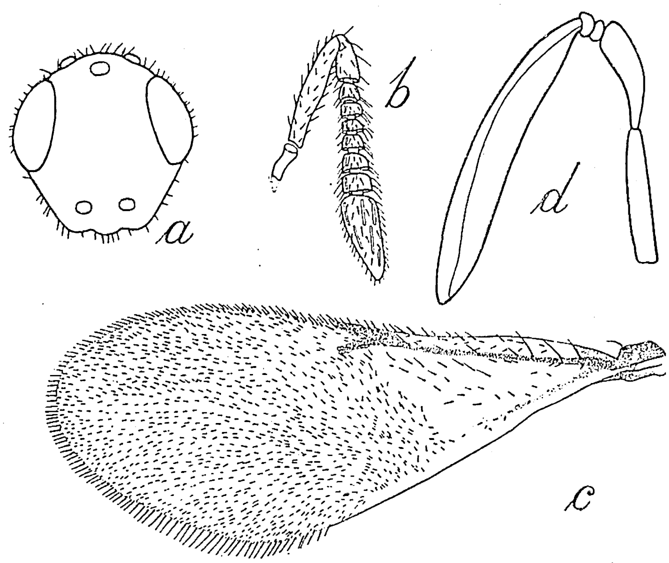

FIG. 2. **a-c** *Litomastix daccaensis,* sp. nov. **a.** head in front, **b.** antenna female and **c.** wing **d.** *Eretmoceras delhiensis,* sp. nov. female, antenna

This species runs in couplet number 8 in Mercet's key (Mercet, *Faun. Iberica* : 444, 1921) to the species of *Litomastix,* but differs all the known species contained therein in the length of the marginal vein being equal to that of the stigmal vein and in the yellowish-brown colour of the middle metatarsus.

Ixodiphagus mysorensis, sp. nov.

Female.—1.0 mm. Black. Head black, seen from above twice as wide as long, somewhat wider than thorax, occipital margin distinct, shagreened ; interocellar space about four times ocellocular space, also ocellocular space is somewhat equal to ocellar diameter ; pubescence brown ; eye pubescence dense and pale brown. Mandibles truncate as in the genus *Ooencyrtus,* except for one minute tooth ; face inflexed.

Antennæ (Fig. 3 a) dark brown, inserted in the middle of face ; scape brown basally, dark brown apically, terminal club segment lighter than

rest of antennæ ; pedicel a little shorter than scape ; scape compressed ; other characters as in figure.

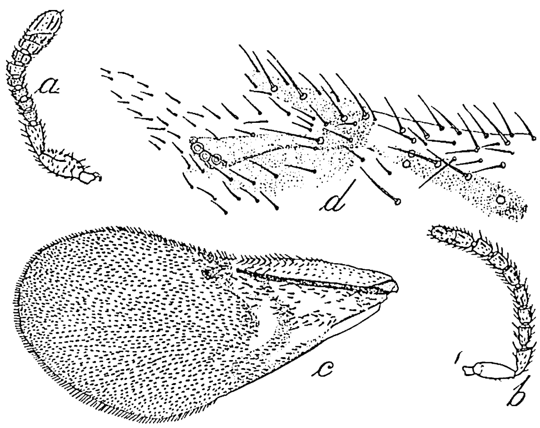

FIG. 3. *Ixodiphagus mysorensis*, sp. nov. **a.** antenna female, **b.** antenna male, **c.** wing, **d.** vein highly magnified.

Thorax black, shagreened ; pubescence brown ; axillæ separated by a faint median carina. Wings (Fig. 3 c, d,) faintly browned behind submarginal vein, marginal vein punctiform, postmarginal vein shorter than stigmal and twice the length of the marginal vein. Legs, except for the light brown tarsi, tibiæ and apical halves of femora, very dark brown. Abdomen dark brown.

Male.—Very similar to female but pedicel is half the length of scape, rest of antennæ as in figure 3 b.

Holotype one female, allotype one male, on two slides ; paratypes several females and males in spirit. Received from the Government Entomologist, Mysore, labelled : "Host : the cattle tick, *Ornithodoros* sp. (Argantidæ), Mysore, July 1940, M. P."

Family *MISCOGASTERIDÆ*

Dinarmus sauteri Masi

1926. *Dinarmus sauteri*, Masi, *Konowia*, **5** : 360.
1939. *Dinarmus coimbatorensis*, Ferrière, *Bull. ent. Res.*, **30** : 163 (new synonym).
1939. *Dinarmus sauteri*, Masi in Ahmad, *Indian J. agric. Sci.*, **9** : 624, ♀♂

This species was originally described by Masi from female specimens only collected by Sauter in Formosa in 1912. Masi redescribed the species recently and Ahmad published a description of a male ; the latter bred the species as a larval parasite of *Lixus truncatulus* (Fab.) boring the stem of *Amarantus* spp. at Pusa.

A comparison of the specimens named by Ferriere as *D. coimbatorensis* with *D. sauteri* has convinced me that the two are identical and hence the synonymy given above.[1] The material from which Ferriere described his form was bred from the same host in South India.

Family *EULOPHIDÆ*

Subfamily ELACHERTINAE

Tribe Euplectrini

Euplectrus plecopteræ, sp. nov.

Male.—Head black, when viewed under high power very finely shagreened but otherwise glossy and smooth ; a longitudinal, straight row of fine setæ adjacent to the orbital inner margin on face (Fig. 4 b) ; vertex margined behind ; below the insertion of antennæ head brown. Eyes dark violet, extremely finely and very sparsely pubescent. Ocelli dark reddish-brown. Head length to head width in the ratio of 9 : 6.5 viewed in front and 9 : 3.5 viewed from above. Scrobes highly polished and shiny. Interocellar space greater than ocellocular space, also ocellar diameter about three-fourths the ocellocular space. Bristles as shown in the figures. (4 a, b).

Pronotal transverse carina faint, behind which the pronotum is smooth and shiny. Mesoscutum reticulately sculptured without any median longitudinal groove, line or carina. Parapsidal furrows complete and deep. Scapulæ shagreened. Axillæ finely shagreened, their inner angles very closely approaching but not contiguous with each other. Scutellum extremely finely shagreened when examined under medium power, except in the posterior area, where it is almost entirely smooth and polished. Mentanotum highly polished. Propodeum highly polished, with the usual complete and well developed median longitudinal carina ; spiracles close to the anterior end of the lateral sulcus.

Antennæ (Fig. 4 d) inserted just on an imaginary line drawn from lower orbital borders ; space between orbital margin and the scapal base is equal to that between the points of insertion of the scapes themselves ; scape cylindrical, pale yellow, equal in length to the first two and a half of the funicular segments combined ; rest of antenna yellowish ; pedicel equal to the first funicular segment in length, with two spines subapically ; ring-joint fused to the base of the first funicular segment; all the funicular segments subequal ; club biarticulate, equal to about one and three-fourths of the preceding segments combined, terminal club segment over three-fourths the basal in length, with a short cylindrical nipple-like process apically; sensoria of club and last funicular segment continuous and fused.

[1] Vide also footnote in PRUTHI and MANI, *I.C.A.R., Misc. Bull.*, **30** : 9, 1940.

Abdomen pale brown but transversely banded dark brown before apex as shown in figure 4 a.

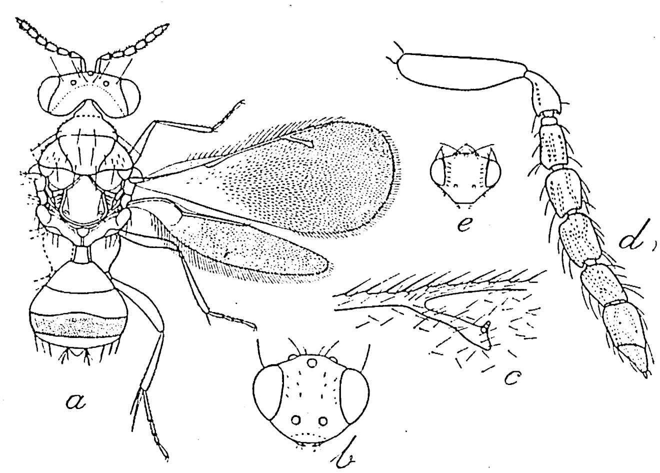

FIG. 4. *Euplectrus plecopteræ*, sp. nov. **a**. male, **b**. head male in front, **c**. vein highly magnified, **d**. antenna highly magnified, **e**. front view of head of *E. bicolor* (From Masi).

All legs including their coxæ pale yellow; the longer spur of hind tibiæ almost equal to the first two tarsal segments combined in length. Wing as in figure 4 a, c.

Holotype one male dissected on a slide, paratypes one male on a slide, two males on card strips; several other paratype males on card strips in the collection of the Forest Entomologist, Forest Research Institute, Dehra Dun. Received from the Forest Entomologist, Dehra Dun, labelled: "parasitic on larva of *Plecoptera reflexa*, Allahabad, P. N. Chatterji collection, 28-iv-1938". In a letter to the Imperial Entomologist, the Forest Entomologist writes that the distribution of this species is as follows: Allahabad, Dehra Dun, and Lahore to Miranpur and Daphar in the Punjab.

This species resembles *Euplectrus bicolor* (Swed.-Haliday)[1] (Fig. 4 e) but differs from the same in the absence of a short median longitudinal carina or line on mesoscutum, and in the transversely banded abdomen. From *E. euplexiæ* Rohw.[2] it is easily distinguished by the scape being a little shorter than the first three funicular segments combined.

[1]SWEDERUS, 1795, *Svensk. Vet.-Akad. Handl.*, **16**: 204.
HALIDAY, 1843, *Trans. ent. Soc. London*, **3** (4): 297.
MASI, 1908, *Boll. Lab. ent. Agr.*, **3**: 122.

[2]ROHWER, 1921, *Ann. Mag. Nat. Hist.*, **7**: 135.

Euplectrus gopimohani, sp. nov.

Female.—Head mostly black, below insertion of antennæ yellowish-brown, somewhat wider than thorax, cheek subequal to the orbital height, with a few scattered punctures; vertex smooth. Lateral ocellar space subequal to ocellocular space.

Antennæ inserted below an imaginary line drawn from the lower orbital borders; scape, pedicel and ring-joint honey-yellow, rest dark brown, setæ white; pedicel equal in length to the first funicular segment, rest of antenna as in figure 5 a, b.

Thorax black; mesoscutum coarsely reticulate medio-posteriorly, finely and lineately shagreened latero-anteriorly, without a median line or furrow; scutum finely shagreened; scutellum finely reticulo-lineate in front and polished behind; pretegular seta black; others white. Venation white.

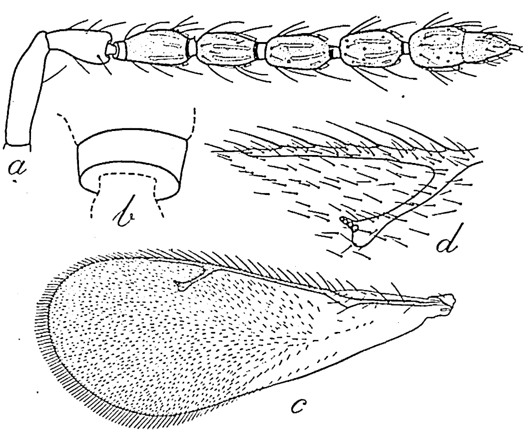

FIG. 5. *Euplectrus gopimohani*, sp. nov. **a.** antenna female, **b.** ring-joint, **c.** wing, **d.** vein highly magnified.

All legs including coxæ honey-brown, only the hind coxæ of a deeper tone, terminal tarsal segments slightly darker; longer spur of hind tibiæ not quite reaching the apex of the second tarsal segment. Abdomen honey-brown ventrally and pale yellow dorsally with brown lateral patches and a faint transverse band before apex; abdominal petiole about half the length of hind coxæ. Propodeum with the usual carina. Wing as in figure 5 c, d.

Male.—Head black, below insertion of antennæ reddish. Thorax black. Mesoscutum coarsely reticulo-lineate, which reticulations look like prominent longitudinal carinæ at extreme apex. Scutellum as in

female. Antennæ dark brown, except the reddish-brown scape, pedicel and ring-joint. Legs reddish-brown, hind coxæ deeply so. Abdomen black at lateral margins, darkened apically and for the rest dark brown. Otherwise as in female.

Holotype one female, allotype one male, paratypes one female and one male all in spirit. Received from the Jute Specialist, Tejgaon, Dacca, labelled : "No. 7, parasite of indigo caterpillar, *Laphygma exigua*, Bashbari, Dacca, bred by Gopi Mohan Das, April, 1940." One male paratype has yellowish head.

This species approaches *E. nyctemeræ* Crawf.[1] and *E. plecopteræ* very closely but differs in the sculpture of scutellum, absence of basal abdominal spot and in antennal colouration.[2]

Subfamily APHELININAE

Tribe Aphelinini

Encarsia isaaci, sp. nov.

Female.—About 0.9 mm. long. Eyes hairy. Head mostly yellowish-brown. Antennæ mostly yellow, with scape and pedicel above and the terminal club segment infuscated brown ; scape equal to the first two funicular segments combined, pedicel and first funicular segment subequal, second funicular segment very slightly longer; third and fourth segments equal to the second, first club segment nearly equal to the last funicular segment, flattened, second segment somewhat shorter, flattened, brownish, both the club segments longer than wide. Mandibles weakly tridentate.

Pronotum black. Mesonotum anteriorly in the middle dark brown, yellow otherwise. Axillæ dark brown, but somewhat lighter posteriorly than anteriorly. Scutellum bright yellow. Metanotum brown. Propodeum dark brown at the sides. All the legs yellow, the last tarsal segments slightly browned, hind tarsal segments short and with stiff bristles. Fore wings slightly infuscated between the marginal vein and anal margin. Distal part of marginal vein (the portion beyond the abrupt break) relatively long ; postmarginal vein obsolete ; all the veins brown. Abdomen black with a yellowish-brown oblique patch laterally from the spiracles, terminal portion yellow.

Holotype one female dissected on a slide. Received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled : "C. S. No. 227, bred from the nymphs of *Aleurolobus barodensis*, Cuttack, (Orissa), Manzur Ahmad collection, 17-ix-1937."

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[1] CRAWFORD, 1912, *Proc. U. S. nat. Mus.*, **42** : 9.

[2] *E. gopimohani* differs from *E. bicolor* (Swed.-Haliday), also a parasite *Laphygma exigua*, mainly in the absence mesoscutal line.

This species very closely resembles *Encarsia flaviclava* Howard,[1] but differs in the yellow scape, dark second club segment, different proportions of funicular segments, shorter ovipositor and absence of a dark patch at lateral anal angles of abdomen.

Encarsia muliyali, sp. nov.

Female.—About 0.7 mm. long. Eyes very finely hairy. Head yellowish-brown, mandibles indistinctly tridentate. Antennæ yellow, relatively more slender than in the foregoing species, scape longer than the combined lengths of the first two funicular segments, pedicel about one-third the length of scape, first funicular segment about one and a half times the length of pedicel, second funicular segment shorter, third and fourth subequal and each also distinctly longer than the second, club not flattened, its segments equal to the last funicular segment in length. Rest of body yellow, except the yellowish-brown pronotum. Hind tarsal segments relatively long, with slender bristles. Distal part of submarginal vein relatively short.

Holotype one female on a slide, paratypes several females in spirit. Received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled : "P. C. S. No. 23C, bred from nymphs of *Aleurolobus barodensis*, Cuttack (Orissa), Manzur Ahmad collection, 2-xii-1938."

This species is readily distinguished from *E. isaaci* by the general colour of body, cylindrical club, slender antennæ and hind tarsal segments.

Tribe Pteroptricini

Eretmoceras delhiensis, sp. nov.

Male.—0.4-0.5 mm. long. Reddish or brownish-orange. Head somewhat reddish at vertex, paler in front, wider than thorax ; viewed in front nearly as long as broad ; cheek about one and a half times the length of eye. Antennæ as shown in the figure 2 d, orange or yellowish-brown. All legs yellow with the tarsi brown.

Veins brown, marginal vein about six times as long as thick. Wing clear of pubescence behind the submarginal vein, also with an oblique hairless line subparallel to the marginal vein running proximad from the stigma.

Types two males on a slide. Received from the Second Entomologist (Dipterist), I.A.R.I., New Delhi, labelled : "P. C. S. No. 192, bred from nymphs of *Neomaskellia bergii* on sugarcane, Imperial Agricultural Research Institute, New Delhi, M. S. Anwar collection, 7-xii-1938."

[1]Howard, 1894, *J. Linn. Soc. London* (*Zool.*), **25** : 97.

Subfamily TETRASTICHINAE

Tribe Tetrastichini

Aprostocetus krishnieri, sp. nov.

Female.—2.5 mm. long. Dark metallic blue or dark metallic greenish. Head (Fig. 6 a) dark metallic green, shiny; at vertex width to the length in the ratio of 5 : 2; minutely punctate; somewhat wider than thorax; ocellocular space about half the interocellar space; scrobes moderately deep and complete; cheek subequal to orbital height, somewhat flat, without sculpture, with a median longitudinal line from orbit to mouth and deeper near orbit than below; mandibles tridentate.

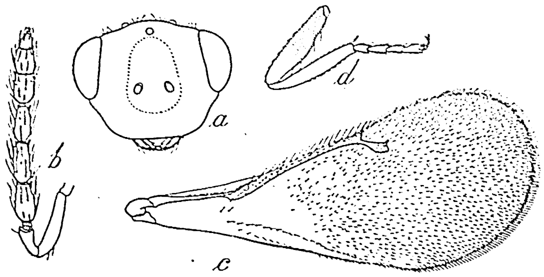

FIG. 6. *Aprostocetus krishnieri*, sp. nov. **a.** head in front, **b.** antenna female, **c.** wing, **d.** hind leg.

Antennæ dark brown; scape brown, somewhat lighter below basally; rest of antennæ as shown in the figure 6 b. Thorax smooth, mesonotum with complete and deep parapsidal furrows and a median longitudinal furrow; scutellum with four longitudinal furrows; propodeum finely rugose, lateral carinæ more prominent than median carina; there are a few scattered minute punctures on scapulæ. Wing as shown in the figure 6 c.

Coxæ and femora concolourous with thorax; knees, tibiæ, except apex tarsi, honey-brown; hind leg as in figure 6 d; veins dark brown. Abdomen about one and a half times the thorax, with long white hairs, especially towards apex.

Holotype one female, paratypes several females all on celluloid strips on pin; antennæ and wing of one female paratype dissected on a slide. Received from the Government Entomologist, Coimbatore, labelled: "Coimbatore, from *Lixus truncatulus* grubs in *Amarantus* stems, P. N. Krishna Ayyar collection, 5-viii-1939."

THE PEA LEAF-MINER, *PHYTOMYZA ATRICORNIS* (MEIGEN), IN INDIA

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and

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(*Received for publication on 24th February,* 1941)

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I. INTRODUCTION

The Indian pea leaf-miner, was identified as *Phytomyza atricornis* (Meigen) for the first time in 1937, and this identification along with preliminary observations on its life-history was communicated to the 26th session of the Indian Science Congress, held at Lahore (Ahmad and Gupta, 1939). This leaf-miner is common and widespread throughout Europe, United States of America and several other countries as a pest of many economic plants like pea, chrysanthemums, *Cineraria,* etc. Lefroy (1906) recorded a leaf-mining fly under the name of cruciferous leaf-miner and Fletcher (1919) also mentioned it under the same name, stating that nothing was known of its status as a pest. Although the identity of these flies was not determined then, it is fortunate that they were carefully preserved in the Imperial Pusa Collection. These specimens, as well as those bred and collected by the present authors since 1937, have been examined and identified as *Phytomyza atricornis* (Meigen). It is thus now possible to say that the reports made from India over thirty years ago under the name of cruciferous leaf-miner are authentic records of the occurrence of this species.

After the shifting of the Imperial Agricultural Research Institute to Delhi, the attack of this fly to leaves of pea and several other plants

growing in the environs of this new site was found to be serious enough to call for attention. It may be mentioned that considerable amount of work has been done on this pest in Italy, England and United States of America, but as the conditions prevailing there are very different from those in India, it was expected that the fecundity, development, seasonal history, number of broods, food-plants, etc., of the pest may be different under Indian conditions. From what follows it will be found that these expectations have turned out to be true in several important aspects of the activity of the pest and many new food-plants have been added to the host list. The investigation was carried out by the second author (R.L. Gupta) while undergoing post-graduate training in Entomology at the Imperial Agricultural Research Institute, New Delhi, under the supervision of the first author.

Since the pest has been identified from India only recently, a brief account of what is known about it in other countries has been included here in the interest of Indian readers.

Our thanks are due to Dr. H. S. Pruthi, Imperial Entomologist, for giving us all facilities for working on this pest.

II. SYSTEMATIC POSITION

Phytomyza is, in number of species, the second largest genus of the leaf-mining flies of the family Agromyzidæ (Diptera). The present species was first described as *Phytomyza geniculata* by Macquart in 1835, but as it was preoccupied by another Agromyzid described by Brulli in 1832, *Phytomyza atricornis* (Meigen), 1838 is the correct name for the species.

A revised latest description of the adult (Pl. 1, Fig. 9) by Cohen (1936) is reproduced below in original.:—

"Interorbital space and ventral region of face yellow; two subequal superior orbital setæ; 1 to 2 inferior orbital setæ; cheek equal to a third of half the depth of eye; antennæ black, 3rd segment, quadrate, slightly longer than broad; arista almost bare; scarcely more than twice the length of the 3rd antennal segment; mesonotum entirely black with a light grey bloom; pleuræ narrowly yellow; 4 pairs of stout dorsocentral setæ; acrosticals absent; femora, tibiæ and tarsi dull black: knees yellow, feet brown or black; wings hyaline; 2nd, 3rd, & 4th segments of costal vein as $4 : 1 : 1\frac{1}{2}$; veins 2 and 3 subparallel, vein 4 nearly straight; halteres yellow; squamæ and cilia dark brown; Length 2-2.5 mm."

III. DISTRIBUTION

Phytomyza atricornis is widely distributed and besides India, it is recorded from Great Britain, Holland, Russia, Australia, North America,

Italy and New Zealand. It is known under different common names in various countries according to the plants attacked. In England it is known as the chrysanthemum leaf-miner and occurs all over the British Isles, where chrysanthemums are grown. In New South Wales it is a pest of *Cineraria* leaves and is accordingly called the Cineraria leaf-miner. In Italy it is referred to as the pea leaf-miner, where it is an important pest of the cultivated peas (*Pisum sativum*). Lefroy (1906) found it mining the leaves of several cruciferous plants at Pusa (India) and mentioned it as the cruciferous leaf-miner.

In the Imperial Pusa Collection we have specimens of the fly from Pusa (Bihar), Chakwal (Punjab) and Delhi. Rahman (1940) has recorded it on *toria* and *sarson* from Lyallpur (Punjab). Recently members of the Entomological Section visiting several other parts of the Punjab, viz., Gurgaon, Rohtak, Karnal, etc,. have reported the same nature of attack on pea and cruciferous plants and it is, therefore, very likely that the pest is actually much more widely distributed than is known to us at present.

IV. Food-plants

The larvæ of this fly are eminently polyphagous and attack a large number of plants belonging to several Natural Orders. Seguy recorded 72 host plants and bred the flies from 23 different species of Compositæ, 7 of Cruciferæ, 4 of Leguminosæ, 3 of Labiatæ and several members of Liliaceæ, Linaceæ, Malvaceæ, Papaveraceæ and Polemoniaceæ. In India the specimens of the fly in the Imperial Pusa Collection are labelled as having been bred from leaves of pea, mustard, linseed, bean and cauliflower. A systematic search was made to find out as many hosts of the fly as possible under Indian conditions. A list of such plants from which the immature stages of the fly were bred to adult stage is given below:—

*1.	Pea (*Pisum sativum*)	Leguminosæ
2.	Mustard (*Brassica campestris* var. *sarson*)	Cruciferæ
3.	*Toria* (*Brassica napus*, var. *dichotoma*)	,,
*4.	Cauliflower (*Brassica oleracea*, var. *cauliflora*)	,,
*5.	Cabbage (,, ,, *capitata*)	,,
*6.	Knolkohl (,, ,, ,, *caula rapa*)	,,
7.	Turnip (*Brassica rapa*, var. *lorifolia*)	,,
8.	Radish (*Raphanus sativus*)	,,
*9.	*Taramira* (*Eruca sativa*)	,,
10.	Safflower (*Carthamus tinctorius*)	Compositæ
11.	*Helichrysum bractaetum*	,,
12.	Lentil (*Lens esculenta*)	Papilionaceæ
13.	Berseem (*Trifolium alexandrinum*)	,,
*14.	*Kirao* (*Pisum arvense*)	,,

15.	*Marwaini* (*Melilotus parviflora*)	Papilionaceæ
16.	*Saharphonka* (*Tephrosia purpurea*)	,,
17.	Hollyhock (*Althaea rosea*)	Malvaceæ
*18.	*Khubaji* (*Malva sylvestris*)	,,
19.	Barley (*Hordeum vulgare*)	Graminæ
20.	Carrot (*Daucus carrota*)	Umbelliferæ
21.	Brinjal (*Solanum melongena*)	Solonaceæ
22.	Potato (*Solanum tuberosum*)	,,
23.	*Petunia phœnicea*	,,
*24.	Linseed (*Linum usitatissimum*)	Linaceæ
25.	*Palak* (*Spinacea oleracea*)	Chenopodiaceæ
*26.	Poppy (*Papaver somniferum*)	Papaveraceæ
*27.	Nastertium (*Tropoeolum majus*)	Geraniaceæ
*28.	Phlox (*Phlox drummondi*)	Polemoniaceæ
29.	Super Violet (*Viola odorata*)	Violaceæ

Of the 29 host plants of *Phytomyza atricornis* listed above, those marked with asterisks are previously known from other countries; the remaining 18 species of plants are new additions to the host list, which is still by no means exhaustive and further researches would probably bring to light several more host plants.

V. NATURE AND EXTENT OF DAMAGE

The first indication of damage done to the leaves is due to the activity of the adult females which puncture tender leaves at numerous places with their ovipositor for the purpose of feeding on the plant juice or of oviposition. These pale yellow minute specks later change into prominent protuberances, due to the increased activity of the injured parenchyma. When there are only few tender leaves on freshly sprouted plants, the intensity of these punctures is sometimes so high that the leaves become etiolated and plants growing under conditions of lack of moisture may wither away altogether.

The more serious damage done to the crop is, however, that by the larvæ, which mine into the leaves, eating through the mesophyl and leaving the two epidermal layers intact. The food-manufacturing work of the leaf is thus considerably interfered with and while in serious cases the attacked leaves wither away altogether, in cases of mild attack flowering and fruiting activities are considerably reduced.

The pest is extremely serious in glass houses throughout England, where chrysanthemums are grown and while in fields the injury is obvious only in spring and autumn. In the glass house with suitable temperature conditions the insect can multiply all the year round and sometimes very rapidly, thus greatly hampering the commercial growing of these plants.

According to Britton (1911) the damage in Connecticut due to another closely allied species viz., *Phytomyza chrysanthami,* has been so great that the commercial growing of plants like chrysanthemums, marguerites and some other Compositæ has been given up.

At Delhi, last year (1937) pea crop sown on the farm of the Imperial Agricultural Research Institute was very severely attacked soon after germination and but for abundant water-supply the plants would have died. Twenty-five leaves of pea collected from the field at random on 3rd, 15th and 23rd March were examined for the number of punctures and immature stages of the fly and the results are set forth in Table I below:—

TABLE I. *Intensity of attack on pea leaves.*

Date	No. of leaves examined	Number of Punctures		No. of larvæ	No. of pupæ	No. of larvæ and pupæ		No. of sound leaves	% sound leaves
		total	per leaf			total	per leaf		
3.iii.38	25	275	11	92	141	233	9	4	16
15.iii.38	25	343	14	112	153	265	11	2	8
23.iii.38	25	210	8	74	151	225	8	3	12

It will be noticed that there were as many as 8-14 punctures, 8-11 larvæ and 2-4 pupæ per leaf, and only 8-16% of the leaves examined were free of insect damage. Thus the severe damage, the wide distribution of the pest and the large number of economic plants attacked, all testify to the serious potentialities of the insect.

VI. LIFE-HISTORY

Copulation.—Adults which emerged in the beginning of March in the laboratory, began to copulate 36-48 hours after emergence. When the female is mature, it remains stationery before an approaching male otherwise it moves away briskly. During copulation the female remains stationery occasionally vibrating its wings, while the male with its wings closed, sits tightly over the female, holding the first abdominal segment with the first pair of legs, the middle of the abdomen with the second pair, and the terminal portion of abdomen with the last pair of legs. The duration of copulation varies from 15 minutes to 1½ hours. When it is brief, it is usually repeated. Both polyandry and polygamy are common.

Oviposition and mode of feeding.—After the copulation is over, the female is seen cleansing its ovipositor with its legs. It may then start

making punctures on the leaf either for feeding or for oviposition. For this purpose the female raises her abdomen on its hind legs, turns the tip of abdomen downwards so that the ovipositor is almost vertical on the leaf surface. It then pierces the leaf-tissue, stretches the ovipositor obliquely and revolves it under the epidermis like a gimlet, withdrawing and pushing it again and again. In this manner a triangular blotch is formed, with its apex at the point of entry of the ovipositor into the leaf tissue. This triangle

TABLE II. *Number of eggs laid per female*

		PAIR No. 1	PAIR No. 2	PAIR No. 3
Date of emergence		1st March, 1938	5th March, 1938	14th March, 1938
Date of copulation		3rd March, 1938	8th March, 1938	16th March, 1938
Number of eggs laid on each day after emergence	1st-4thday	—	—	—
	5th ,,	1	15	6
	6th ,,	10	18	10
	7th ,,	36	13	23
	8th ,,	34	0	34
	9th ,,	17	10	25
	10th ,,	16	24	13
	11th ,,	10	6	27
	12th ,,	20	23	16
	13th ,,	25	27	14
	14th ,,	25	50	20
	15th ,,	0	32	15
	16th ,,	10	17	8
	17th ,,	12	4	15
	18th ,,	16	8	17
	19th ,,	15	12	7
	20th ,,	7	8	12
	21st ,,	9	4	14
	22nd ,,	14	7	7
	23rd ,,	11	8	11
	24th ,,	11	6	9
	25th ,,	9	11	8
	26th ,,	7	23	6
	27th ,,	12	11	4
	28th ,,	7	11	2
	29th ,,	10	4	2
	30th ,,	9	0	3
	31st ,,	2	2	1
	32nd ,,	—	1	—
	33rd ,,	—	3	—
Total No. of eggs.	..	355	358	329
Date of death ♂	..	27th March, 1938	6th April, 1938	1st April, 1938
,, ,, ,, ♀	..	5th April, 1938	11th April, 1938	18th April, 1938
Longevity (days) ♂	..	26	32	18
,, ,, ♀	..	35	37	35
Pre-oviposition period.	..	4	4	4
Post-oviposition period.	..	5	5	4

measures about 0.3 mm. at its base and about 0.45 mm. along its other two sides. The egg is deposited singly in this cavity (Pl. I, Fig. 2) and the ovipositor is withdrawn. A series of eggs may be laid in similar chambers excavated close to one another before the female has an interval of rest.

It may be mentioned, that eggs are laid in only a few of the punctures made in the above manner. Most of these are made for the purpose of feeding, in which case the female turns round after withdrawing the ovipositor and sucks the plant juice with its mouth parts. Males, being not capable of making such holes, are seen waiting in attendance close to the females and licking the juice after the latter have left. The maximum number of punctures found on a single leaf in nature was 38 and in captivity 125. Melis (1935) records as many as 154 punctures on one leaf in nature and 112 on two leaves made by a female in captivity in 7 hours.

Number of eggs and oviposition period.—Cohen (1936) in England found that on an average a female laid 51-72 eggs during her life time, the maximum in 24 hours being 17. Melis (*loc. cit.*) in Italy records only 38 eggs per female. Under Indian conditions the species seems to be much more prolific, as will be seen from the oviposition record of some freshly emerged females in Table II.

It will be seen from the above table that the total number of eggs laid per female is as high as 329-358, which is about five times the maximum figure so far known. The pre-oviposition period is about 4 days and the post-oviposition period 4-5 days. The number of eggs laid daily during the first ten days of oviposition, with the exception of first and second remains very high. After this it drops down gradually till during the last few days very few eggs are laid. It will be further noticed that eggs are laid almost daily; during an oviposition period of a little less than a month, there are only one or two days when no egg is laid. The maximum number of eggs laid on a single day was 50.

The egg and its incubation.—The egg (Pl. 1, Fig. 3) is colourless, somewhat translucent and oval-elongate in form, its length (0.28-0.33 mm.) being a little over twice the breadth (0.13-0.15 mm.). The surface is quite smooth and without any reticulation. The egg being deposited inside the leaf-tissue, is in direct contact with the cell-sap of the leaf and, therefore, very sensitive to drought. Eggs exposed to dry air soon shrivelled up and failed to hatch. The incubation period and viability of eggs kept in *situ* at room temperature and different incubator temperatures are given below (Table III).

TABLE III. *The Incubation period*

Temperature.	No. of eggs kept.	Incubation (days)		No. of larvæ hatched.	% viability.
		Average.	Range.		
Incubator temperature :—					
13°—15°C	105	3.91	3.5-5.0	88	83.8
16°—18°C	163	3.15	3.0-4.0	138	84.6
20°—23°C	110	2.74	2.0-3.5	92	83.6
Room temperature :—					
23°—28°C	393	2.2	1.55-3.0	348	88.5

The egg stage varies from 3.9 days at 13-15°C, to 3.2 at 16-18°C, 2.7 at 20-23°C and 2.2 at 23-28°C. The percentage viability is fairly high, 84-89% of eggs being viable under these conditions. According to Cohen (*loc. cit.*) the incubation period is $3\frac{1}{2}$ to 4 days at 18°C, and according to Melis (*loc. cit.*) it is 2 days at room temperature during March and April.

The larval stage.—The freshly hatched larva (Pl. I, Fig. 4) is white, with the exception of the mouth-parts which are smoky-brown. Later, due to the food contents the abdominal portion shows a greenish yellow tinge. It is subcylindrical in form with maximum thickness in the middle, tapering both ways, and ending in a narrow point anteriorly and a bluntly rounded terminal portion posteriorly. When full grown, it measures about 3.0 mm. long and 0.75 mm. broad (Pl. I, Fig. 5).

The larva is essentially a solitary feeder, there being one individual in a gallery. When two or more eggs are laid close together, the larvæ make divergent galleries; therefore it is very rare that they coalasce into one another. With its mouth-hooks formed of bidentate mandibles, (Pl. I, Fig. 6) the larva feeds on the mesophyl of the leaf without injuring the two epidermal layers. These galleries often run in lines parallel to the principal vein but may also follow a zigzag course (Pl. I, Fig. I). As the larva grows in size the mines widen and become more distinct, being marked by pellets of frass and excreta throughout their course.

Melis records that the larvæ pupate 14-15 days after hatching at room temperature (March-April) ; Cohen mentions a larval period of 10-11 days at 18° C. We made a large number of observations on the larval period at different temperatures by cutting leaves containing freshly hatched larvæ and placing them in incubators after dipping the petiole in water. This precaution was necessary as the entire larval period must be completed in the same leaf, since once removed from its gallery, the larva cannot restart

a gallery on a fresh leaf and it dies helplessly. These observations are summarised in Table IV.

TABLE IV. *The duration and viability of larval stage at different temperatures*

Temperature.	No. of larvæ kept.	Larval duration (days)		No. of pupæ obtained	% viability.
		Average	Range		
Incubator temperature :—					
13°—15°C	21	11.1	11.0—11.5	13	61.9
16°—18°C	149	8.4	8.0—9.0	80	53.7
20°—23°C	80	5·6	5.0—6.0	51	63.8
Room temperature :—					
23°—28°C	347	5.2	4.0—6.0	178	51.3

The larval duration was thus found to range between 11.1 days at 13-15°C to 5.2 days at 23°-28°C. The percentage viability varied from 51-64% and was highest at about 22°C.

The pupal stage.—Towards the end of its larval life, the larva prepares a wide chamber and pupates within its last larval skin, which hardens in due course (Pl. I, Fig. 7). The freshly formed puparium (Pl. I, Fig. 8) is long, and oval, and pale yellow in colour but with age assumes a reddish-brown or a dark brown colour. It measures on the average 2.0×0.9 mm. More often pupation takes place below the lower epidermis of leaves.

TABLE V. *The duration and viability of pupal stage at different temperatures*

Temperature	No. of pupæ kept.	Pupal period (days)		No. of flies emerged.	% viability.
		Average	Range.		
Incubator temperature :—					
13°—15°C	31	15.1	14.5-16.0	22	71.0
16°—18°C	36	11.5	11.0-12.0	25	69.4
20°—23°C	51	8.1	8.0- 8.5	39	76.5
Room temperature :—					
23°—28°C	152	6.8	6.0- 8.0	100	65.8

According to previous records the pupal period is 11-12 days at 18°C (Cohen, 1936) and 12-14 days at room temperature (Melis, 1935). Our observations detailed in Table V show that it varies from about 15 days at 13-15°C to about 7 days at 23-28°C. The percentage viability is 70-76, being maximum (76.5%) at about 22°C.

Longevity of adults.—Like many other flies the adults of *Phytomyza atricornis* are short-lived in the absence of food. At room temperature (23°—28°C) the longevity was only 2 days. At incubator temperatures of 13-15°C and 16-18°C they lived for 2-4 days. When honey solution was supplied as food or when the adults were offered fresh pea leaves daily, from which they were able to obtain their nutrition, they lived up to a maximum of 29 days (average 15 days) at room temperature (23°-28°C), 86 days (average 61.5 days) at 16-18°C and 50 days (average 27 days) at 13-15°C. This shows that given suitable conditions of temperature and food the adults are very long-lived.

Number of broods and seasonal history.—The pea leaf-miner seems to be essentially an inhabitant of temperate regions and it flourishes under conditions of moderate temperature and high humidity. Therefore, in a tropical country, such as India, its activities are restricted mainly to spring (January to April) and like several other flies with similar temperate seasonal requirements, e.g., the tur-pod fly, *Agromyza obtusa*, the linseed fly, *Dasyneura lini* etc., it æstivates during the period of unfavourable high temperature.

The adults of *Phytomyza atricornis* make their appearance for the first time generally in January and sometimes in December. By February, pea and other spring host-plants of the fly are just sprouting and offer suitable material for its feeding and oviposition. At a temperature of about 17°C, which usually prevails during February, one generation of the fly is completed in a little less than a month. Later in March and April, with the warming of the season one brood requires only half a month (Table VI). Thus from February to April, there are 4-5 generations. Active breeding stops in May, but at cooler places and specially on late-growing spring hosts, restricted breeding is observed to continue until June. In the laboratory, the last maggots pupated by the beginning of June, and the summer and autumn were passed in the pupal stage. The emergence of flies started in December-January and this completed the seasonal life-cycle. Although there was no emergence in autumn in the laboratory, it seems some flies do emerge about August in nature, as a few maggots were found mining leaves of lucerne in September at Delhi. These were extremely few and do not seem to be of much importance. Thus the normal breeding season of the fly under Delhi conditions extends from January to May, with active breeding only from February to April.

TABLE VI. *The duration of one generation under different conditions*

Temperature.	Pre-oviposition period.	Incubation period.	Larval period.	Pupal period.	Total period for one generation.
Incubator temperature :—					
13°—15°C	6	3.9	11.1	15.1	36.1
16°—18°C	5	3.2	8.4	11.5	28.1
20°—23°C	4	2.7	5.6	8.1	20.4
Room temperature :—					
23°—28°C	4	2.2	5.2	6.8	18.2

VII. CONTROL MEASURES

1. *Mechanical methods.*—Mechanical control consists of the systematic collection and destruction of infested leaves as soon as possible after the appearance of the pest so that its activities are nipped in the bud. Owing to low temperature the development of the first brood is rather slow and the number of flies commencing it is also usually limited. Therefore it should not be difficult to remove the few affected leaves in a period of well over a month. It is true that the plucking of too many leaves may bring about a marked interference in the growth of the plants, particularly when they are very young but when it is remembered that most of these affected leaves have to wither away on account of the attack, it is as well to collect and burn them. With proper irrigation such plants sprout again and it is not necessary to resow the crop. Of course this method must be supplemented by the removal and destruction of alternative host plants in and around the main crop and the fact that there are a large number of host plants attacked by this species discounts the value of this method to some extent.

2. *Chemical control.*—In spite of the fact that all the pre-imaginal stages of the pest are passed within the leaf tissue, they are amenable to contact sprays, because of the very thin epidermis which protects them. One part of nicotine sulphate and two parts of soft soap dissolved in 400 parts of water kill all the immature stages excepting the advanced pupæ. It is, therefore, necessary to repeat the spraying after a period equivalent to the duration of egg, larval and half pupal stage of the pest which varies from 11-16 days according to the season. This spray also acts as a temporary repellant against further oviposition.

Attempts have also been made by Melis in Italy to poison the adults by spraying the crop with poisoned sweet solutions but the results so far obtained have been only a partial success. This seems to be due to the fact that flies have abundant supply of natural nutrition in the form of leaf juice available, and unless the sprays used are more attractive this method cannot form an effective control. It would further be seen that male flies which are without independant means of obtaining the natural food are more likely to feed on these sprays. This fact is recorded by Melis. Trials with various attractants mixed in the poisoned sprays are worthy of further investigation. It will also be useful to discover suitable season and time for such sprays e.g., it is likely that on hot and bright days artificial food supplied may be more in demand.

3. *Natural enemies.*—Larvæ of *Phytomyza atricornis* were found parasitised by an internal parasite *Solenotus* sp. The parasite lays 1-4 eggs within the host body and the grubs, on hatching, go on feeding for 4-5 days (during March-April). They then pupate within the body of the host, though sometimes they may crawl out and pupate naked. The adult parasite emerges from the pupa after another 4-5 days. The parasite was first observed as early as end of February. It is therefore suggested that the collection and destruction of leaves infested with the pest should be carried out judiciously, by enclosing them in wire gauze cages through which the parasite can escape but the host cannot.

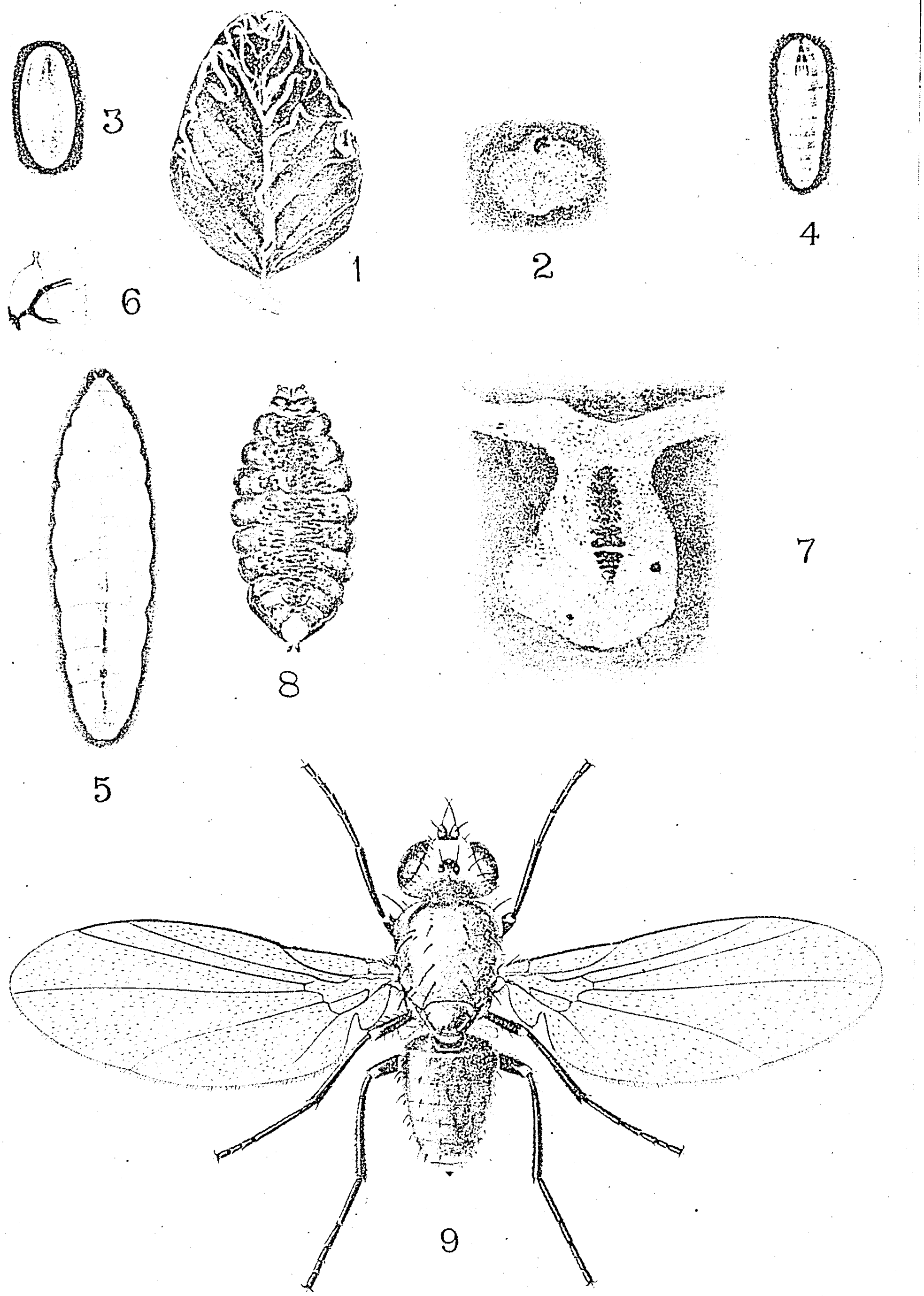
VIII. SUMMARY

Hitherto known in India under the name of Cruciferous leaf-miner, this species has been now definitely identified as *Phytomyza atricornis* (Meigen). It is a common and widespread leaf-miner throughout Europe, United States of America, Australia and several other countries. The larvæ of this fly are eminently polyphagous, over 6 dozens host plants being already known; 29 species of plants have been found subject to the attacks of the leaf-miner in India, of which 18 are new records. The damage to the leaves is partly due to the numerous punctures made by the female for feeding purposes, but chiefly on account of the mining of larvæ into the leaves.

During March and April when the temperature is 23°-28°C, one generation is completed in about 18 days (pre-oviposition period 4 days, incubation period 2 days, larval period 5 days, and pupal period 7 days). The number of eggs laid per female so far known is only 51-72, but under Indian conditions as many as 329-358 eggs per female were not uncommon.

The morphology of its various stages has been described and illustrated by figures.

An Eulophid parasite, *Solenotus* sp., has been bred from the larval stage of the fly.



PHYTOMYZA ATRICORNIS (MEIGEN)

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EXPLANATION OF PLATE I.

Fig. 1. Attacked leaf showing egg-spots & larval mines
Fig. 2. Egg-spot & the egg inside (× 30).
Fig. 3. Egg taken out. (× 90).
Fig. 4. Larva, freshly hatched (× 90).
Fig. 5. Larva, full grown (× 30).
Fig. 6. Head of larva showing mouth parts, highly magnified.
Fig. 7. Pupa inside the mine (× 10).
Fig. 8. Pupa taken out (× 30).
Fig. 9. Adult fly, male (× 36).

A METHOD OF CUTTING SECTIONS OF TICKS AND INSECTS*

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The paraffin-celloidin method, though commonly used for cutting serial sections of large chitinous objects, is hardly suitable for minute specimens, inasmuch as the coating of celloidin prevents the direction of such specimens being accurately determined and this makes it difficult to orientate them, while being imbedded in the paraffin medium. This is particularly so when the solvent used for celloidin is clove oil, instead of a mixture of ether and alcohol, for the former imparts a brownish colour to the celloidin medium and thereby makes it translucent. Moreover, the paraffin-celloidin method was found to be very unsuitable for cutting serial sections of whole specimens of ticks.

Numerous trials were carried out to test the possibility of avoiding the use of the double imbedding method in the case of ticks. The ordinary single paraffin method proved of little value, though it would appear to have been used with success by Robinson and Davidson (1913) in cutting serial sections of the tick, *Argas persicus*. Unfortunately, these authors have not indicated the precise duration of the paraffin bath, the only statement made by them on this point being that "the duration of the paraffin bath must not be prolonged for a moment more than is absolutely necessary". As for chitin "softeners", three of these were tested: (1) Amann's chloral-phenol method, as described by Langeron (1913) and which is claimed to have the advantage of retaining the "intégrité des échantillons" and of conserving exactly the forms of the chracteristic organs "sans contraction, ni gonflement". This fluid, however, appeared to be too drastic in its effect to be of value for a histological study of the internal tissues. (2) Murray's modification of Amann's formula, involving a previous double fixation of the material with formalin and Gilson-Carnoy solution. This method failed to produce results comparable to those claimed to have been obtained by Murray (1937) in the case of the tongue of the blow-fly and the gut of the earwig. (3) Diaphanol, which in conjunction with dioxan (*infra*), was successfully used by Sapre (1940) in cutting serial sections of the tick, *Ornithodorus papillipes*. This substance, while otherwise a highly efficient "softener" for the chitin, was not found to be entirely free from the tendency

* This paper was read at the 28th session of the Indian Science Congress, held at Benares in January, 1941.

to exert an injurious effect upon the internal tissues of ticks, and in this respect, the writer is in agreement with Eltringham (1933) in the latter's remark that, "in spite of statements to the contrary, it (diaphanol) does cause, in the softer tissues, changes which preclude accurate diagnosis of their histology." In order to avoid over-treatment with diaphanol, Pavlowsky (1931) suggested that the hardness of the chitin should be tested from time to time with the point of a needle; this, however, can hardly be relied upon in practice.

It was eventually found that, with a suitable fixative, Peterfi's methyl benzoate method was capable of being utilized with a fair amount of success in cutting serial sections of even highly chitinized ticks. Trials were carried out with a number of fixatives, including those of Carnoy, Duboscq-Brasil, Bles, Bouin, Mukerji (1937) and Petrunkevitsch (cited by Imms, 1939), but the best results were obtained with Sherlock's fluid consisting of 95 parts of saturated solution of mercuric chloride and 5 parts of acetic acid (cited by Eltringham, 1930). The advantage of the last-named fixative is that it is free from alcohol, which, as is well known, has a hardening effect on the chitin. For the same reason, the dioxan (diethyl-dioxide) method was substituted for dehydration in the higher grades of alcohol. As, however, dioxan vapour is toxic for the human subject (Gatenby and Painter, 1937; Carleton and Leach, 1938), a series of tests was carried out with "solvax", which has been claimed by its manufacturers (Messrs. Flatters and Garnett, Manchester) to be as effective as dioxan and at the same time free from the drawback of the latter, as mentioned above. These tests seemed particularly desirable in view of the highly satisfactory results reported to have been obtained from its use by Eltringham (1937) in his studies upon the sexual characters of the males of certain Indian moths, for, on this subject he wrote as follows: "The use of the fluid named 'solvax', supplied by Messrs. Flatters and Garnett, has enabled me to dispense with strong alcohol, benzol, cedar oil, and similar agents, all of which tend to harden chitin. Solvax will dehydrate rapidly from 20% alcohol and mixes freely with paraffin and with xylol. It is an ideal medium for embedding purposes." Solvax has since proved to be a very suitable reagent for dehydrating insect and tick material and is now used by the writer in preference to either alcohol or dioxan.

The procedure for preparing minute chitinous objects for section-cutting is as follows:—

1. Fix in Sherlock's fluid for 3 hours.
2. Wash in distilled water for 2 minutes and stain in a strong watery solution of eosin for 3 minutes, in order that the object may be easily seen while being imbedded in paraffin.

3. Transfer to 50% alcohol for 48 hours, with iodine solution for the removal of mercuric crystals. Remove to 'solvax' and leave the object for 48 hours, changing the fluid thrice.
4. Place in methyl benzoate celloidin solution (10 grammes of celloidin dissolved in 1,000 c.c. of methyl benzoate) for 48 hours, with two changes of the solution. Transfer to benzol for 24 hours, changing the fluid once. Place for 15 to 30 minutes in benzol-paraffin at 37°C. This represents Peterfi's methyl-benzoate method.
5. Keep in melted paraffin (melting-point 60°C.) for 1 hour.
6. Imbed in a watch-glass, orientating the object with warm needles under a magnifying glass.
7. With a glass pencil draw a line on the edge of the watch-glass to indicate the long axis of the object.
8. Plunge the watch-glass into cold water, and with a fine needle draw a line on the edge of the wax in continuation of the one previously drawn on the watch-glass in pencil. Using this line as a guide, the object may be cut in any direction, a suitable thickness for the sections being 8 to 10 microns.

The removal of the paraffin and celloidin from the sections should invariably be followed by a momentary immersion of the slides in a 0.8 per cent solution of celloidin in ether-alcohol, as recommended by Guyer (1936). The omission of this step is likely to result in the sections coming off the slides while being passed through alcohols or washed in water.

Very good results were obtained with Mann's eosin-methyl-blue stain. By reason of the rapidity of its action, this stain proved more advantageous than Heidenhain's iron hæmatoxylin.

On the subject of cutting of serial sections of ticks, Cowdry and Ham (1932) have remarked : "After much experimentation it was found that complete serial sections could be only obtained in the case of ticks after their chitinous coverings had been completely removed by careful dissection." Shortt (1936) has likewise recommended the removal of the dorsal chitin and the cutting of "tangential sections of the dorsum, thus avoiding, as far as possible, the hard chitinous parts on the ventral aspect." With the solvax-Peterfi method described above, these precautions have been found to be unnecessary.

Summary

A method is described for cutting serial sections of minute chitinous objects and of whole specimens of ticks. This consists in fixing the material

in Sherlock's solution and dehydrating in 50 per cent alcohol and later in the proprietary preparation known as "solvax". The material is then dealt with by Peterfi's methyl-benzoate method.

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NEW CERAMBYCIDAE FROM INDIA AND BURMA

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(*Received for publication on 28th February,* 1941)

The holotypes and paratypes of the three new species described here are in the Forest Research Institute, Dehra Dun.

Chlorophorus shoreae, new species (Fig. 1)

Ground colour black; pubescence bright yellow with dark markings. Antennæ very dark brown with thin ashy pubescence. Legs dark brown or blackish, with close ashy pubescence, except above on distal half of hind femora and hind tibiæ and tarsi. Head yellow. Pronotum yellow, except three nearly nude black spots: one large discal, pyriform, longer than wide and not reaching anterior and posterior margins, and one on each side before the middle, small. Scutellum yellow. Each elytron with bright yellow and thick dark brown marks; one rather wide yellow stripe extends from near the shoulder, along base to scutellum, then along suture and after curving outwards, is directed back towards the shoulder after giving off a short but wide branch to external margin; a yellow transverse band behind the middle extends from near the external margin (sometimes touching it) to the suture along which it is expanded both anteriorly and posteriorly, the posterior sutural extension sometimes narrowly connected with an apical yellow band with oblique anterior margin.

Ventral surface uniformly covered with dense pale yellow pubescence except the last abdominal segment which is darker. Antennæ short, not reaching to middle of elytra, the third segment a little longer than the fourth. Prothorax a little longer than wide, moderately curved laterally, widest behind the middle. Elytra broadly truncate, the external angles with small points, the inner with 2 still smaller points. The hind femora extend beyond the elytral apex. Length 5 to 7 mm.

Described from thirteen specimens bred from wood of *Shorea robusta*, Dehra Dun, U. P. (M. Bose).

Eunidia xyliae, new species

Head and prothorax red, with silky pubescence of the same colour; antennæ black with very thin pubescence; elytra black with thin uniform greyish pubescence; metathorax and abdomen below obscurely reddish,

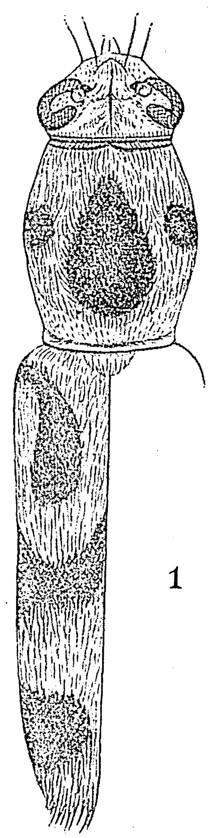
more or less infuscated and with rather close yellowish pubescence ; legs with tibiæ and tarsi black, the femora red basally black distally, the black at apex only on anterior femora but more extensive on the two posterior pairs.

Third antennal segment short and acutely angulate. Prothorax wider than long, rather wider anteriorly than posteriorly, with well marked but rather shallow anterior and posterior transverse grooves above. Elytra with small fairly close punctures from base to near the round apex. Length 6.2 mm. to 7.8 mm.

Two specimens reared from *Xylia dolabriformis* ; Prome, Burma, (M. H. Desai.)

The new species is distinguished by its colour from other known species.

Smermus fisheri,* new species (Fig. 2)



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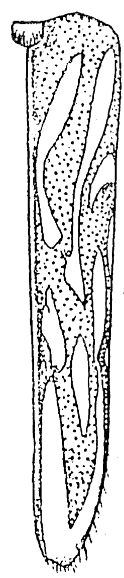

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Fig. 1. *Chlorophorus shoreae*, new species. Fig. 2. *Smermus fisheri*, new species, right elytron.

Head blackish with dull golden pubescence on frons, genæ and a median dorsal line. Antennæ with scape dark brown, dull reddish basally ; segments 3 to 11 dull testaceous but dark apically. Prothorax blackish with dull golden pubescence in three lines above and rather more thinly on whole lateral area. Scutellum with dense dull golden pubescence. Elytra dark brown with dull testaceous elongate marks as in figure 2. Under surface with fairly uniform dull golden pubescence. Legs dark brown.

Head with scattered and rather coarse punctures on frons and genæ. Eyes reaching about half way to mandibles. Antennæ about four times as long as body ; scape gradually enlarged to near apex, then somewhat narrowed. Prothorax longer than wide, nearly cylindrical, slightly roundly protuberant laterally near anterior margin and again near the middle ; with very distinct moderately close punctures. Elytra obliquely truncate at the apex, the angles not markedly produced ; surface with very thin pubescence, distinctly punctured on basal half. Length 12 mm. to 16 mm.

*Named after Mr. W. S. Fisher of the United States National Museum.

Described from five specimens reared from stems of *Clerodendron infortunatum*, Myitkyina and Anisakan, Burma (R.Hlaogh).

This species has some resemblance to *S. mniszechi* Lac., but is darker, the markings on the elytra are more elongate on the whole and the elytral apices are not emarginate.

Synonymy of Necydalis indica

Necydalis indica Gardner [*Indian For. Rec.*, **2** (4) : 128, 1936], described from Chakrata, U. P., is preoccupied by *N. indica* Pic. [*Mel. Exot. Ent.*, **3** : 19, 1912] from Murree, Punjab and is now renamed *N. indicola* Gardner. It is possible that the two species may be identical but Pic's description is too brief for a definite statement on this point.

NOTES ON SOME INDIAN PARASITIC HYMENOPTERA, WITH A DESCRIPTION OF A NEW CYNIPID

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(*Received for publication on 28th February,* 1941)

INTRODUCTION

During the course of my studies on hymenopterous parasites at Pusa and Delhi, I came across two interesting species of Braconids, one of which, parasitic on *Sylepta lunalis* Guen. is new and is being described by my colleague Dr. K. B. Lal elsewhere under the name *Apanteles pusaensis*. The other species, *Apanteles paludicolæ* Cameron, is parasitic on *Sphenarches caffer* Zell. Biological notes on these two species are given.

Two species, one an Encytrid and the other a new species of parasitic Cynipid wiedemann, were also bred by me from *Sphaerophoria javana* Wiedemaun predating on *Aphis laburni* Kaltenbach in Delhi. The new Cynipid is described below under the name *Amblynotus syrphidiphagus*. Notes on the Encyrtid, *Aphidencyrtus aphidivorus* (Mayr), which is recorded for the first time from India, are also added.

I wish to express my sincere thanks to Dr. Hem Singh Pruthi, Imperial Entomologist, for giving me all facilities for work and to Mr. M. S. Mani for valuable suggestions in the description of the new parasite.

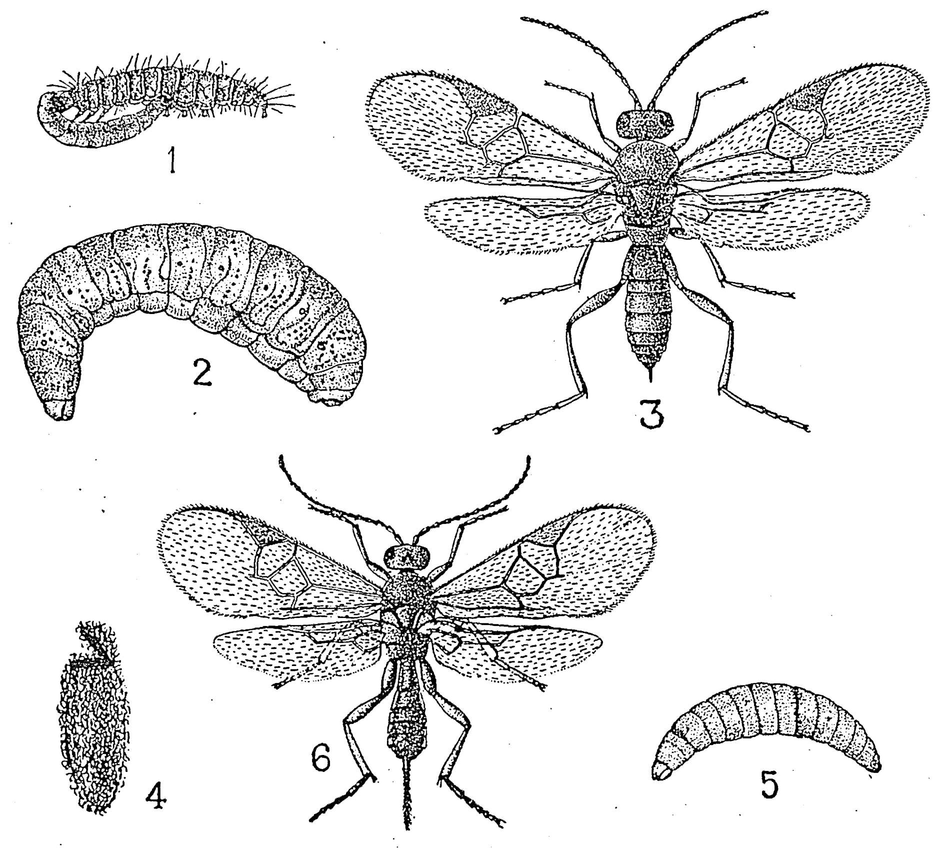
BIOLOGICAL NOTES

Apanteles paludicolæ Cameron

This parasite was first described by Cameron (1909) and later redescribed by Wilkinson (1928) as parasitic on the caterpillars of the Pterophorids, *Trichoptilus paludum* Zell. and *Platyptilia molopias* Meyrick in Ceylon. Johnston (1930) reported that it was the most important parasite of *Sphenarches caffer* in Sudan where the latter attacks the buds of *Dolichos lab-lab*. At Pusa, it has been bred from the caterpillars of *Sphenarches caffer*, a minor pest of *Lagenaria vulgaris*, *Dolichos lab-lab*, *Cajanus cajan* and *Cucurbita pepo* in different parts of India.

At Pusa, the leaves of *Lagenaria vulgaris* are attacked by the caterpillars of *Sphenarches caffer* throughout the year. Beginning from July up to the end of March, the parasites are seen in numbers, flying among the leaves of *Lagenaria vulgaris*, evidently in search of host caterpillars.

The female parasite settles down now and then warily near the host larvæ to deposit the eggs. Frequently after attempting to oviposit on some caterpillars, the parasite was actually observed not to lay eggs on them. Such caterpillars, however, on examination, proved to have been parasitised already. From this it would appear that the female parasite is gifted with a prescience to discriminate between a parasitised and a non-parasitised individual. The whole act of oviposition occupies about three minutes. The host does not appear to be affected by parasitisation in the initial stages of its development. Later on, however, the caterpillar loses its



FIGS. 1—4. *Apanteles paludicolæ* Cam., **1.** Grub emerging from larva of host; **2.** Full-grown larva; **3.** Adult female; **4.** Cocoon with clear-cut lid.
FIGS. 5—6. *Apanteles pusaensis* Lal. **5.** Grub; **6.** Adult female.

normal green colour, turns yellow, and becomes sleepy. Just before the emergence of the full-grown parasitic larva from the host body, the quiescent caterpillar begins to move about and squirm its body painfully bent in the form of an arc. Very soon a white point, which is the head of

the parasite, comes out from about the middle region of the abdomen between third, fourth and fifth abdominal segments (Fig. 1), ventro-laterally on the left side. The oval slit after the emergence of the larva can be seen clearly. The full-grown larva (Fig. 2) after emergence from the host is of Braconid shape, curved at the cephalic end. It is 5 mm. long and 1 mm. broad across the thorax. In colour it is white and opalescent with dark brown mandibles. There are nine pairs of spiracles, the first pair on the mesothorax and the next eight pairs on the first eight segments of the abdomen. The head and the thirteen post-cephalic segments are clearly marked. The last segment is modified into a caudal vesicle. The integument of the vesicle is attached to the last larval skin in the cocoon. Hypopleural swelling is present on each side of the abdominal segments, one to nine inclusive, and on the metathoracic segment, each being ventral to the spiracle. Dorsal humps are very poorly developed. Soon after emergence from the caterpillar, the parasitic larva spins a cocoon on the leaf, within which it pupates. The larval period inside the body of the host is about 20 days in winter. During July-September it is only 12 days. The pupal period according to Johnston (1930) varied from 4-7 days in Sudan. At Pusa, it varied from 9 days in winter to 6 days during July-September. The adult emerges from the cocoon by cutting a clean lid (Fig. 4). In Sudan, the percentage of parasitism was reported to be only 28, whereas at Pusa it varied as follows :—

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
1933-34	—	—	—	—	48.0	64.5	47.0	33.3	30.0
1934-35	55.5	58.3	42.8	45.4	59.2	80.6	43.6	30.7	22.2
1935 (Concld.)	44.4	45.4	37.5	40.0	50.0	42.8	—	—	—

Apanteles pusaensis* Lal (MS.)

This Braconid (Fig. 6) parasitises the caterpillars of the Pyralid, *Sylepta lunalis* which feed on the leaves of the grape-vine, *Vitis vinifera,* at Pusa. It is remarkable that inspite of the normal and regular occurrence of superparasitism, 60-70% of the larvæ are destroyed in the field between July and August. About 20-40 full-grown parasitic larvæ emerge from each host caterpillar. The full-grown larva (Fig. 5), on emergence from the caterpillar, is creamy-white and opalescent. It is curved in the form of an arch, and is 4 mm. long and 1 mm. broad. Immediately after emergence, it spins a cocoon and pupates. The pupal period is about 5-6 days in July-August.

*The description given here is not intended to establish the specific name of this new species, which is being described by Lal elsewhere.

SYSTEMATIC NOTES

Superfamily CHALCIDOIDEA

Aphidencyrtus aphidivorus (Mayr)

1875. *Encyrtus aphidivorus*, Mayr, *Verh. zool.-bot. Ges. Wien*, **25** : 712.
1909. *Encyrtus aphidivorus*, Masi, *Boll. Lab. zool. Gen. Agr. Portici*, **3** : 96.
1921. *Aphidencyrtus aphidivorus*, Mercet, *Faun. Ibérica*, p. 343.

This Encyrtid, which is recorded here for the first time from India, occurs all over Europe, where it has been noted as a parasite of the Braconid, *Aphidius brassicæ* Marsh, itself a parasite of *Brevicoryne brassicæ* (Linn.). It has also been reported to parasitise the Cynipid parasites of the aphid, *Aottria vittrix* Westw. in Europe. From this it would appear that this is an important hyperparasite of aphides.

The genus *Aphidencyrtus* Ashm.[1] itself has not been recorded so far from India. It resembles the genus *Ooencyrtus* very closely, especially in the wing venation. Body is metallic coloured. The first two or three funicular segments are short and moniliform, the following segments usually longer than thick. At least two last segments are somewhat broader than long. The antennal club is long, thicker than the rest of the antennæ and over one half as long as this. The axilliæ approach each other very closely but do not touch. Scutellum smooth or polished. Wings hyaline, stigmal vein shorter than the combined length of the marginal and post-marginal veins, the marginal vein itself is less than twice as long as thick. Postmarginal is weakly developed but somewhat longer than marginal. Abdomen broad, oval, flat above and much shorter than thorax. In the male the flagellum of antenna is clavate, hairy, with the segments about twice as long as thick.

About a dozen species are known, most of which occur in the United States of America. The species *A. aphidivorus* is easily distinguished from all the other species of the genus by the following characters :

The third and fourth funicular segments of the female are much onger than the rest, club is equal to the four preceding funicular segments combined. Marginal vein is a little longer than the stigmal vein. In the male the middle funicular segments are as long as their apical breadths. The middle legs are black, with the apices of the tibiæ brown. Further, the head is finely shagreened. Scutellum and mesonotum are minutely reticulo-scaly. Length of body : Female 0.95 mm., male 0.89 mm.

Superfamily CYNIPOIDEA

Amblynotus syrphidiphagus, sp. nov.

Female.—Length about 1.5 mm. Black. Antennæ dark brown, with the tip black. Legs brown with the hind coxæ very dark brown

[1] W. H. Ashmead, 1900 *Proc. U. S. nat. Mus.*, **22** : 340, 347, 398.

and hind femora reddish-brown, leg pubescence very fine. Venation light brown.

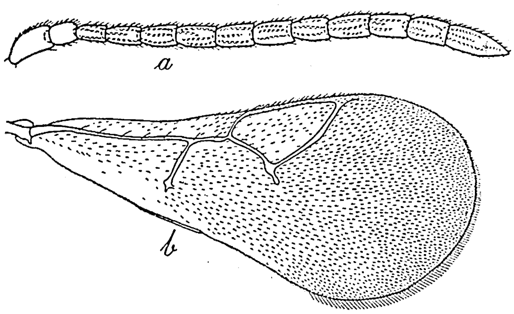


FIG. 7. *Amblynotus syrphidiphagus*, sp, nov, female. **a**. antenna ; **b**. wing.

Head viewed from above wider than thorax, length to width in the ratio of 4 : 8. Occiput strongly concave. Vertex very finely striated. Ocellocular space about two and a half times the ocellar diameter, interocellar space twice the ocellocular.

Head viewed in front about round. Antennæ inserted just above the middle of face. Face densely striated, and below the insertion of the antennæ densely clothed with silvery-white hairs. Scape dark brown, pedicel dark brown, globose and about half the length of scape, first funicular segment somewhat longer than pedicel. Club solid with a very faint transverse line at apical third. Rest of antenna as shown in figure 7 a, and distinctly longer than the thorax and head combined. Thorax finely striated, mesopleura smooth. Scutellum with two prominent grooves in front and coarsely rugose behind ; parapsidal furrows deep and complete. Wings as shown in Figure 7 b. Abdomen shorter than thorax, smooth and shiny ; hairs at base on first apparent tergite light brown. Hind coxæ with dense light brown hairs. Second apparent abdominal tergite almost equal to the first.

Holotype one female in spirit, paratypes three females in spirit. In the Imperial Pusa Collection, New Delhi. Parasitic on the larvæ of the Syrphid, *Sphærophoria javana*, a predator on *Aphis laburni*, at Delhi, E. S. Narayanan coll.

This species chiefly differs from all the other known species of the genus *Amblynotus*, which is being recorded for the first time from India, in the antennæ being distinctly longer than the thorax and head combined, and in the finely striated thorax and the third antennal segment being equal to the fourth in length.

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PTERYGOSOMID MITES FROM TWO NORTH INDIAN LIZARDS

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(*Received for publication on 26th June,* 1940)

I. Introduction

The family Pterygosomidæ comprises eight genera of medium-sized trombidiform mites, which are all parasitic on lizards, with the exception of *Pimeliaphilus podapolipophagus* Trägardh, a species found under the elytra of an Egyptian beetle, *Pimelia* sp. Of another species, *Hirstiella trombidiformis* Berlese, the host is unknown, but in all probability it is a lizard. *Pterygosoma*, the type-genus of the family, was erected by Peters (1849) for a parasite of *Agama mossambica* Peters. Subsequently, several authors have described new forms occurring on lizards, but the most important contributions to our knowledge of these mites are made by Trägardh, Hirst and Lawrence. Trägardh (1905), in addition to describing several new forms, published valuable notes on the structure and development of the species he encountered. Hirst (1926) redescribed and figured many imperfectly known forms and placed the taxonomy of the group on a sound basis. Lawrence (1935 and 1936) reported upon a large collection of Pterygosomids parasitic on South African lizards. This author being in the unique position of having a nearly complete collection of this group from a definite zoo-geographical region, contributed valuable information on host-parasite relationships in the Pterygosomidæ and described three new genera and several new species.

Indian Pterygosomidæ are, as yet, only very little known. Hirst (1917) described *Geckobia indica* as occurring on *Hemidactylus gleadovi* in Upper Sind. In a subsequent paper (1926) he described another species, *G. gleadoviana*, from the same host and three other species, *G. diversipilis*, *G. simplex*, and *G. hindustanica*, from the South Indian lizard, *Hemidactylus leschenaulti*. In the same paper this author recorded the occurrence of what he considered *Pterygosoma neumanni* (Berlese) on the garden lizard (*Calotes versicolor*) from Madras.

The present paper deals with the Pterygosomid parasites of the common wall lizard, *Hemidactylus flaviviridis* Rüppel and the garden lizard, *Calotes versicolor* (Daudin) of the Punjab. Nearly one hundred living specimens of the wall lizard were examined in Lahore during the past three summers and a few at Kasur and Hissar in the summer of 1936. Not a

single wall lizard captured in these three towns was found to be free from the two species of *Geckobia* described below. A dozen wall lizards examined at Khanewal (Western Punjab) in August 1937, however, did not show any Pterygosomid parasites. This is in conformity with Lawrence's experience (1936) with the acarine parasites of South African Geckonidæ, as he states that 'a number of individuals from the same locality are either all positive or all negative for parasites'.

Only twenty-four specimens of the garden lizard *C. versicolor* were examined at Lahore and two at Hissar; all of them were found to harbour Pterygosomids.

II. MITES PARASITIC ON *Hemidactylus flaviviridis* RÜPPEL

1. **Geckobia orientalis**, sp. nov.

Female.—Body usually a little broader than long. Dorsal hairs of more or less uniform size (the anterior ones a little shorter), slender and distinctly plumose. Dorsal scute lightly chitinised; eyes present. Peripheral hairs stout, long and plumose. Ventral surface with hairs similar to those of the dorsal surface and evenly distributed all over the under surface, except the mid-ventral part which is almost bare.

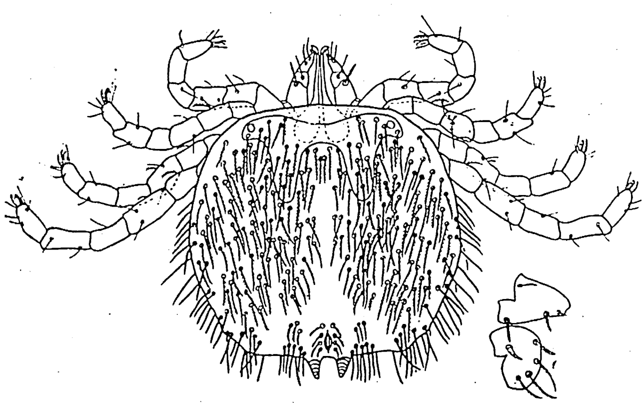

FIG. 1. *Geckobia orientalis*, sp. nov., female, dorsal view, with coxæ highly magnified (shown separately).

Mouth parts somewhat elongated; dorsal hair on the second palpal segment slender and plumose.

Legs gradually increasing in length, from the first to the fourth, but not in thickness. Trochanters of all legs provided with an incrassate hair on the antero-ventral side which is thin and simple on the first leg and pectinate on others. Femora of legs III and IV provided with a pectinate incrassate hair anteriorly and that of legs I and II bearing a simple hair. Coxæ and coxal spurs as in Fig. 1.

Dimensions.—Length of idiosome 0.307 mm., breadth 0.324 mm.

Male.—Body a little broader than long. Dorsal surface as in Fig. 2.

The dorsal scute slightly more heavily chitinised than in female, bearing five pairs of slender, plumose hairs and shaped as in Fig. 2. Spicule (penis) 0.103 mm. long, almost straight, with tip usually protruding backward from the genital aperture situated in the middle line and a little in front of the posterior margin on the dorsal surface. Dorsal and peripheral hairs uniformly long and finely plumose. Ventral surface with plumose hairs increasing in length from front backwards.

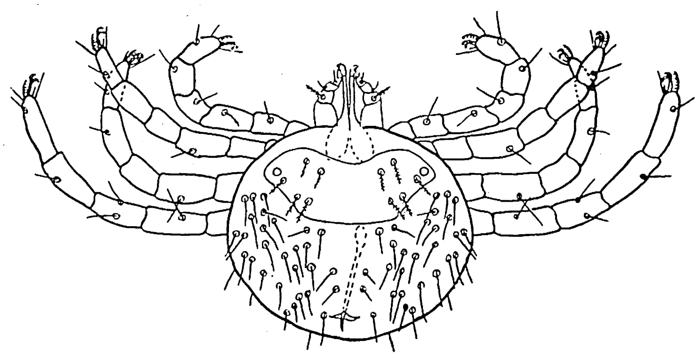

FIG. 2. *Geckobia orientalis*, sp. nov., male; dorsal view.

Mouth parts similar to those of the female but with first palpal segment comparatively much longer.

Legs increasing in length from the first to the fourth but without incrassate hairs on 2nd and 3rd segments as in the female. Posterior common coxæ with only four thickened hairs (coxal spurs), two corresponding to each of the third and fourth legs. Anterior common coxa with two thickened and two simple hairs as in the female.

Dimensions.—Length of idiosome 0.174 mm., breadth 0.197 mm.

Location.—Between the claw and foot-pad of the host.

Distribution.—Central and southern Punjab (Lahore, Kasur and Hissar).

In many respects, this species resembles *Geckobia simplex* Hirst, but differs from it in having a plumose and much more slender seta on the second palpal segment ('first free segment' of Hirst). The mouth parts are also somewhat more elongated than in *G. simplex*. From *Geckobia gleadoviana* Hirst, this species differs in the shape of the dorsal scute and the presence of a thin simple anterior seta on the femur of the first leg, instead of a pectinate incrassate hair figured by Hirst (1926) for that species.

2. **Geckobia kasurensis**, sp. nov.

Female.—Body broader than long. Dorsal surface with hairs as shown in Fig. 3,A; hairs on the dorsal scute uniform in size and distinctly

plumose; but those on the rest of the body increasing in size from scute backwards. Peripheral hairs stout and long with blunt tips and hardly plumose. Dorsal scute shaped as in Fig. 3,A and bearing 15-17 pairs of short, plumose setæ. Ventral surface almost entirely covered in the middle with flattened scale-like pointed hairs (Fig. 3, C-E), the latter tending to become somewhat cylindrical towards the sides and lanceolate posteriorly, most anterior row of hairs as in Fig. 3,C.

Mouth parts normal; dorsal seta of the second palpal segment short, stout and plumose.

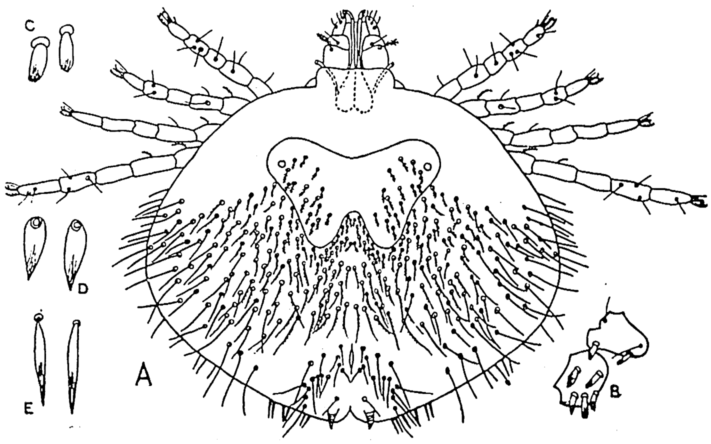

FIG. 3. *Geckobia kasurensis*, sp. nov., A, female dorsal view; B, coxæ; C,D,E anterior, middle and posterior hairs on the ventral surface.

Legs progressively longer from the first to the last. Trochanters of all legs bearing antero-ventrally a hair, which is simple and slender on leg I and stout and pectinate on others. Femora of all legs bearing an anterior hair, which is thin and simple on the first three legs and pectinate on the fourth. Coxæ and coxal spurs as in Fig. 3,B.

Dimensions.—Length of the idiosome 0.432 mm., breadth 0.504 mm.

Male.—Body spherical or a little broader than long. Dorsal surface with a few finely plumose hairs as shown in Fig. 4. Dorsal scute distinct, shaped as in Fig. 4. bearing five pairs of short, plumose hairs. Spicule 0.105 mm. long and curved. Ventral surface with plumose hairs quite small in front but increasing in length backward. Mouth parts as in female. Legs increasing in length from first to fourth. Trochanters and femora without antero-ventral incrassate hairs as in female. Coxal hairs similar to those in the male of *G. orientalis*.

Dimensions.—Length of idiosome 0.252 mm., breadth 0.27 mm.

Location.—Found all over the body of the host, particularly behind the shoulder, on the flanks, legs and under the ventral scales.

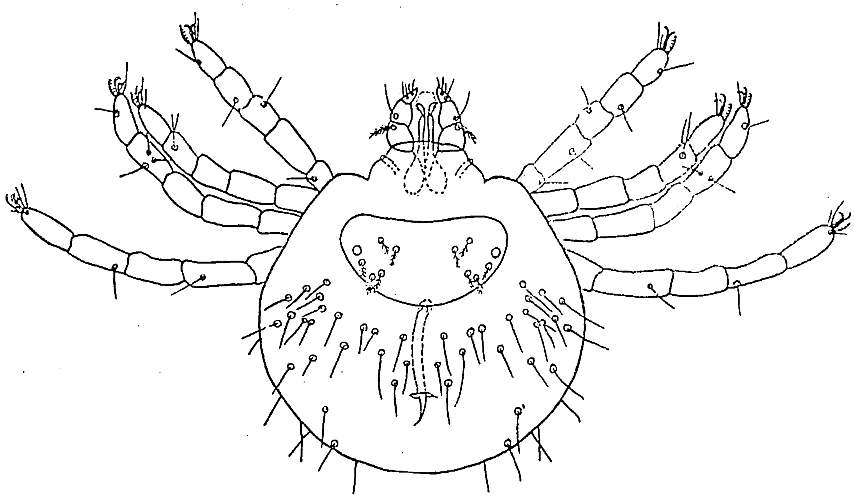

FIG. 4. *Geckobia kasurensis*, sp. nov., male; dorsal view.

Distribution.—Central and southern Punjab (Kasur, Lahore and Hissar).

This species comes nearest to *Geckobia hindustanica* Hirst, from which it can be distinguished on account of a much smaller number of hairs on the dorsal surface of the body and the absence of the incrassate plumose hair on the third femur, figured by Hirst (1926, Fig. 11).

3. **Pimeliaphilus sharifi,*** sp. nov.

Female.—Body sub-rectangular in shape, somewhat narrower in front. Dorsal surface with thirteen pairs of long, slender plumose hairs, three pairs of them being situated on the dorsal scute and one pair on the antero-lateral border; arranged as in Fig. 5. Dorsal scute shaped as in figure, with anterior pair of hairs being smaller than others. Eyes present. Ventral surface with a pair of slightly plumose hairs behind the posterior common coxæ and two pairs of short simple hairs around the anal field.

* Named after Dr. M. Sharif, the well known Indian acarologist.

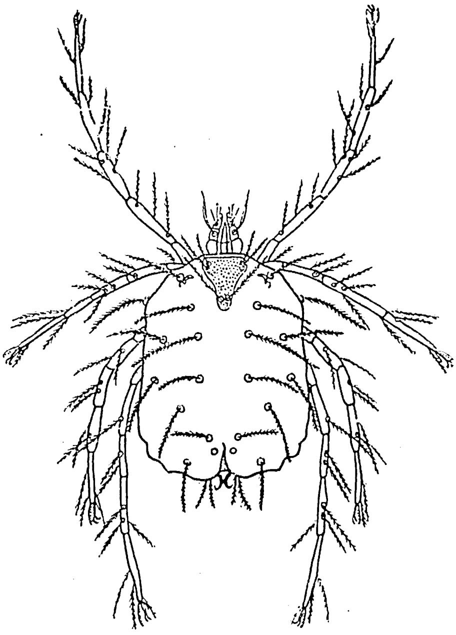

FIG. 5. *Pimeliaphilus sharifi*, sp. nov., female; dorsal view.

Mouth parts forming a conical mass; second palpal segment with a dorsal, flattened, blade-like, finely plumose hair.

Legs long and slender, with numerous plumose hairs. Fusion of the coxæ not complete, with a fine suture between the two components of each common coxa.

Dimensions.—Length of idiosome 0.804 mm., breadth 0.633 mm.

Location.—Hind legs and flanks of the host.

Distribution.—Central and southern Punjab (Lahore and Hissar).

Male.—Unknown.

This species differs from all the other known species of the genus *Pimeliaphilus* in the shape of the dorsal scute and in the arrangement of the dorsal hairs.

III. MITES PARASITIC ON *Calotes versicolor* (DAUDIN)

1. **Pterygosoma neumanni** (Berlese).

1910. *Geckobia neumanni*, Berlese, *Redia*, **6** : 347-48
1925. *Geckobia neumanni*, Berlese, Gli Insetti, Milano p. 96
1926. *Pterygosoma neumanni*, Hirst, *J. Linn. Soc.* (zool.), **36** : 139

Berlese (1910) described a Pterygosomid parasite of *Agama colonorum* from Senegal under the name *G. neumanni*, but his description was meagre and unillustrated. Later in 1925, he published a figure of the female of this species, in which, among other characters, he showed fourteen peripheral hairs on either side of the anal field. Hirst (1926) redescribed this species from specimens which, he considered, belonged to this species, and obtained from the same host (*Agama colonorum*) in Somaliland and from *Calotes versicolor* in Madras. He rightly placed this species in the genus *Pterygosoma* Peters. In his figure of the female he has shown 21-22 peripheral hairs on either side. In the material before me there are specimens with 12-14 peripheral hairs, collected from two garden lizards (*C. versicolor*) at Hissar in the summer of 1936. A large number of specimens collected from twenty-four lizards of the same species at Lahore, however, show 20-25 peripheral hairs on either side. No specimen with an intermediate number of hairs was found. Lawrence (1936) used variation in the number

of peripheral hairs as a character for differentiating related species. But in view of the close similarity between the forms with 12-14 and 20-25 hairs in other characters and their presence on the same hosts both in India and Africa, I consider them only varieties of the same species. Typical *Pterygosoma neumanni* (Barlese) is, therefore, the form the female of which has 12-14 peripheral hairs on either side and occurs on *A. colonorum* in Senegal and on *C. versicolor* in Hissar (Punjab). The form described by Hirst, the female of which has 20-25 peripheral hairs on either side and which occurs on *A. colonorum* in Somaliland and on *Calotes versicolor* in Madras and Lahore, is a new variety, which I propose to name as *Pterygosoma neumanni* var. *hirstielli*.

2. **Pterygosoma neumanni** var. **hirstielli**, nov.

Hirst (1926) described and figured only the female of this variety. In the material before me there is a male which was found under the scales of the tail of a garden lizard at Lahore.

Male.—Body sub-triangular with rounded angles, broader than long. Dorsal surface with a few hairs (Fig. 6), only three on the postero-lateral border of each side, the anterior two being pointed and the posterior one flattened at its tip. Spicule (penis) 0.176 mm. long, shaped as in Fig. 6, anteriorly directed (not posteriorly directed as in *P. hystrix* Lawrence and *P. bicolor* Lawrence). The V-shaped chitinous structure enclosing the penis, described by Lawrence for the two above-named species, absent. Genital opening situated in the median line in front of the middle of dorsal surface and flanked on either side by two anteriorly diverging prominent lips. Ventral surface with a few simple hairs.

Mouth parts and legs resembling those of female.

Dimensions.— Length of idiosome 0.36 mm., breadth 0.504 mm.

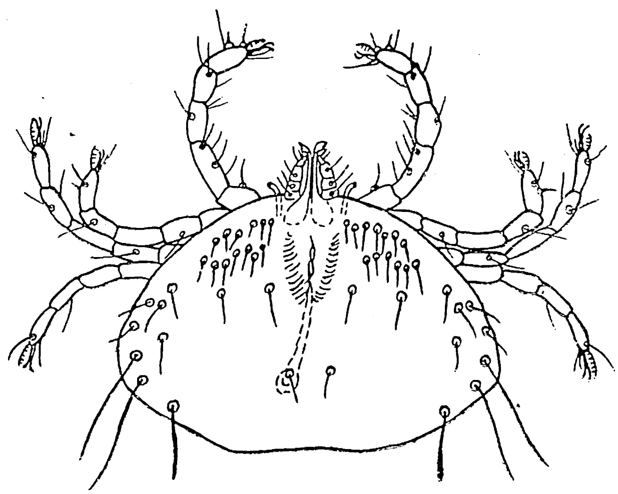

FIG. 6. *Pterygosoma neumanni* var. *hirstielli*, nov., male: dorsal view.

Location.—Under the scales all over the body.

Distribution.—Central Punjab (Lahore).

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SOME OBSERVATIONS ON THE BIOLOGY OF THE CEYLONESE CALOTERMITIDÆ

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CONTENTS

I. INTRODUCTION

The following notes, which do not pretend to be more than fragmentary records, are intended as a contribution towards a knowledge of the general biology of the Ceylonese termites of the family Calotermitidæ, several species of which are of great economic importance in the island. Included herewith are also general observations on the biology of Isoptera and a few of the biological problems which are associated with this group of insects.

Termites are social insects, which live in large colonies or communities in the tropics and to a lesser extent in the warmer temperate regions. On account of the enormous losses caused by their attacks to wooden structures and living trees and shrubs, they are of very considerable economic importance, while to the biologist their habits and economy, as in all social insects, present many fundamental problems of far reaching consequence.

The study of this most interesting and fascinating group of insects is, therefore, not only of considerable practical value but is also of the greatest scientific interest.

Although popularly known as "white-ants", termites are neither related to true ants, nor are they always white. In structure and development, these primitive insects differ widely from the true ants, which belong to one of the most specialized of insect orders. But the social organization of these two widely separated groups is similar in that both form large colonies, both display highly developed social instincts and habits and both exhibit a striking polymorphism and most advanced appreciation of the division of labour.

II. CLASSIFICATION

The termites constitute a distinct insect order, the Isoptera. They are most nearly related to cockroaches, belonging to the order Orthoptera.

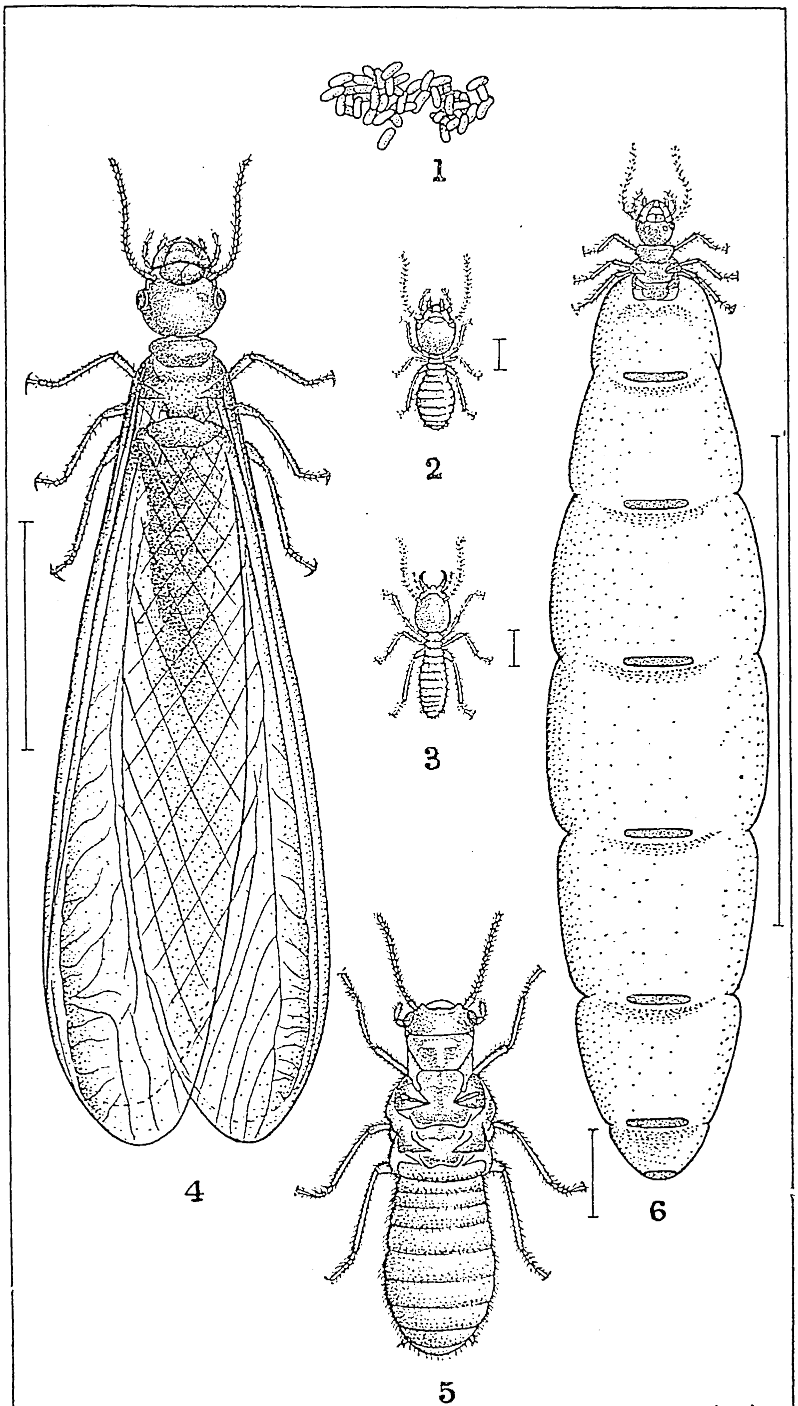
The Isoptera, according to Holmgren (1911a), whose classification is the one generally accepted by systematic workers, is divided into four families : Mastotermitidæ, Protermitidæ, Mesotermitidæ and Metatermitidæ. But as Banks and Snyder (1920) have pointed out, these names, excepting the Mastotermitidæ, are unacceptable according to International Rules of Zoological Nomenclature and should be replaced by Calotermitidæ, Rhinotermitidæ and Termitidæ respectively. Recent workers (Sjöstedt, 1925 and others) also recognize a fifth family, viz., Hodotermitidæ, formerly included in the Calotermitidæ.

As regards genera, there has been a good deal of confusion. Some of the large genera, such as *Calotermes*, were considered to contain subgenera, which resulted in tripartite names. The opinion of most modern authorities is that most of these subgroups are sufficiently characteristic to be elevated to generic rank and this system has been adopted in the present paper, following Kemner (1934) and Light (1930). The genera of Calotermitidæ represented in Ceylon are : *Calotermes*, *Neotermes*, *Cryptotermes* (with the subgenus *Planocryptotermes*), and *Glyptotermes*.

III. GENERAL OBSERVATIONS ON THE BIOLOGY OF ISOPTERA

Before proceeding to a consideration of the biology of the Calotermitidæ, it is desirable to make a few introductory remarks upon the biology of termites in general.

A termite colony is generally established by a pair of winged adults, or the so-called "Royal pair". These forms emerge from the parent nest at certain seasons of the year, generally the rainy season, in large numbers. After a brief dispersion-flight, they alight on the ground, trees or on



FIGS.—1-6 *Hypotermes obscuriceps*

1. eggs; **2.** worker; **3.** soldier; **4.** winged adult; **5.** dealated adult; **6.** queen. (After Jepson).

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wooden structures, according to the habit of the species. The males and females pair, break off their wings (sometimes before pairing) along a humeral suture adapted for the purpose, and select a suitable place on the ground or in wood in which they excavate a cavity for their nest. At the time of swarming, a very heavy mortality of the insects occurs. They are greedily devoured by birds, bats, lizards, frogs, cockroaches, and other animals and only a very few survive to found new colonies. The function of the winged forms is thus the perpetuation of the species by dispersal.

After first pairing, the female (called 'queen') starts laying her eggs in the nest, within which the pair remain, mating taking place at irregular intervals. When the eggs hatch, the parents tend the offspring until such time as the young (commonly called "workers") can look after themselves and take over these functions as well as other duties, such as the building of the termitarium, which, in some species attains an enormous size. On account of their cryptic habits of life, termites live in darkness. In the species which nest in the soil, the queen, owing to a process of post-metamorphic growth, attains an enormous size, about six times her original dimensions (Figs. 1-6). In the primitive termites, however, she undergoes very little or practically no change (Figs. 7-16). The males undergo very little increase in size.

Termites undergo an incomplete metamorphosis. From the eggs laid by the "queen" the young hatch out and develop into various types of adults or castes, each of which has a special function to perform for the welfare of the community. In a typical termite society, the castes met with are :

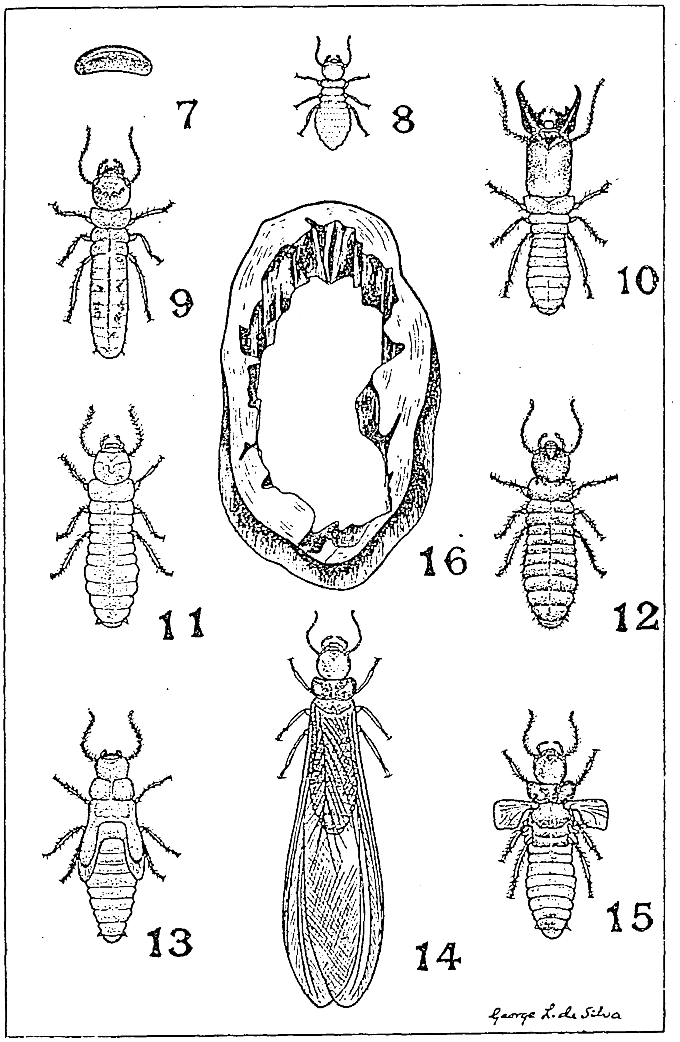
(a) The "workers" (or young), in which both sexes are represented and which are responsible for the work of the colony. They look after the eggs and young and, in the most highly developed species, the reproductive pair also. They forage for food, build the nest and perform other duties.

(b) The "soldiers", easily distinguished by their dark chitinous heads, are usually furnished with powerful mandibles, used to defend the colony against enemies ; the soldiers of some species employ other means of defence as well. This sterile caste is also represented by both sexes.

(c) The reproductive forms consist of two types : winged adults and wingless neoteinic adults, the latter being either apterous or brachypterous. Neoteinics appear in colonies orphaned by the death of the "royal pair" or in subsidiary colonies. They are adults, whose sexual organs have become prematurely developed, that is, before attaining the winged state. The biology of these castes will be referred to later.

The food of termites consists chiefly of cellulose-containing material and hence these insects are destroyers of wood, living or dead, paper,

clothing, etc. They may also attack materials of animal origin such as leather. Some species, which nest in the soil, also grow fungi for consumption by the young and the "royal pair". They also feed on the fæcal matter ejected by the members of the colony, their exuviæ and on their dead or dying fellows. A common and readily observable feature in the economy of termites is 'trophallaxis' or reciprocal feeding. Each termite is constantly licked by other members to obtain exudations from the skin.



FIGS. 7—16. *Neotermes militaris*

7. egg x 6.6 ; **8**. young larva x 3 ; **9**. full grown larva x 3. **10**. soldier x 3 ; **11**. nearly full grown larva x 3 ; **12**. apterous neoteinic adult x 3 ; **13**. nymph with long wing-pads x 3 ; **14**. winged adult x 2.3 ; **15**. dealated adult x 2.3 ; **16**. transverse section of a tea stem hollowed out by *N. militaris*. (After Jepson).

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In all termites except those of Termitidæ, the intestines harbour vast numbers of protozoa. These are regarded as symbionts, useful in digesting the wood eaten by the termites. Cleveland (1924) has demonstrated that termites deprived of their protozoa soon die of starvation.

IV. THE BIOLOGY AND ECONOMIC IMPORTANCE OF THE CEYLONESE CALOTERMITIDAE

The family Calotermitidæ contains forms less highly specialized than those of the families Rhinotermitidæ and Termitidæ. In the last two groups, a well-established colony is of large size, with a population amounting to hundreds of thousands of individuals, while the number of members of a colony of Calotermitidæ is usually limited to a few hundreds.

Members of the Calotermitidæ do not nest in the soil and hence are referred to as "non-subterranean termites". Very recently, however, an exceptional case has been recorded by Light (1937) where *Calotermes* (*Paraneotermes*) *simplicicornis* (Banks) has been found to nest at, or near, the wood in the soil. In this respect the species is unique, as no other species of Calotermitidæ being known to nest in, or travel through, the soil.

Species of Calotermitidæ construct no true nests or termitaria but merely excavate series of longitudinal galleries in logs, dead, dying, or living woody plants or in dressed timber. With the exception mentioned above, they do not travel through the soil but may migrate from one tree or piece of timber to another, provided that the roots or pieces of timber are in contact with the infested material. Thus, they neither build mounds nor (except *Paraneotermes*) construct earthen shelter-tubes to travel in, as most of the soil-nesting species do. The Calotermitidæ, however, with the aid of their saliva and liquid fæcal matter utilize particles of wood and excrement to seal up openings to their galleries.

Kalshoven (1930) records that in artificial colonies, *Neotermes tectonæ* Damm. forms short galleries (runways) of excrement on the outside of the wood the insects inhabit, and Light (1937) records the construction of earthern runways by the unique *Paraneotermes*.

Representatives of the Calotermitidæ nest in wood and there is no outward manifestation of their presence except in the case of the dry-wood-nesting species which expel their fæcal pellets from their galleries.

In the so-called "queens", or reproductive forms, of the Calotermitidæ there is practically no post-metamorphic growth and consequently they do not attain the great size of the females of the higher termites. Their brown colour also persists, whereas in the higher forms the much distended abdomen is white, except for the small brown, abdominal segmentary markings. The "royal pair" is free to move about in the nest and not imprisoned in a cell as in the higher forms.

A Calotermitid "queen" lays comparatively fewer eggs. The youngs which hatch out from these eggs develop either into reproductive adults or sterile soldiers. Thus, there is in this group of termites no true worker caste, the communal functions of the workers being undertaken by the immature forms.

In nature, members of the Calotermitidæ feed exclusively upon wood. They inhabit moist, or dry, dead wood or living woody plants. They also can subsist on other cellulose-containing material, such as paper, cotton, clothing, etc. Their intestines abound with protozoa which aid in the digestion of such materials. The insects void characteristic fæcal pellets and also liquid fæcal matter. The pellets are minute, sand-like grains of uniform shape, being laterally impressed, oval and hexagonal in transverse section. Their colour varies according to the wood upon which the insects have fed but is generally a pale cream. The pellets are found in the termite galleries and chambers and when in excess are ejected from them. Accumulations of such expelled fæcal pellets are commonly seen beneath the wood infested by the dry-wood-nesting species. But in species which nest in dead moist wood or living plants, the fæcal pellets are not so readily seen as, owing to their moist surroundings, most of the pellets disintegrate and are converted into an earth-like powder which often cakes into hard lumps. Moreover, much of the fæcal matter of these insects is liquid. In the case of tea bushes attacked by *Neotermes militaris* Desn., the main cavity formed by the insect is usually packed with this earthy matter into which adventitious roots sometimes find their way.

To the time of writing there have been recorded from Ceylon fourteen species and one variety of Calotermitidæ, representing four genera (formerly regarded as subgenera) and one subgenus. Most of these species have been discovered in recent years and five of them and one variety await description. Many of the species are of considerable importance as they are very destructive to living plants of economic value, particularly tea (*Camellia sinensis*), and to building woodwork, furniture and any article in which wood is employed. In addition to the damage caused to dressed timber, the dry-wood-nesting termites, whose injury in Ceylon has until recently been confused with "dry-rot", have also been suggested by Jepson (1933) to be a possible factor in the etiology of sprue. This hypothesis, although supported by much circumstantial evidence, awaits confirmation.

In the following pages are recorded all the species of Calotermitidæ so far known from Ceylon, with very brief notes on habitat, economic importance, distribution and other items of interest. Detailed accounts of the more important economic species, accompanied by observations on biology, have appeared in various local publications (Jepson, 1926-1936 ; Hutson, 1929-1933 ; King, 1937).

Genus **Calotermes** Hagen, *s. str.* Banks

The species of *Calotermes* usually inhabit tree stumps or dead wood of living trees and may also occasionally attack the living tissue. A few of them (*e.g.*, *C. minor*, *C. hubbardi*) are known in the United States to attack dressed timber, causing damage similar to that of other dry-wood-nesting termites.

C. pintoi Kemner

Kemner described this species in 1932. It is the first, and so far the only, record for this typical genus either from India or Ceylon. Only three other species are reported from the Oriental Region, one by Holmgren from the Celebes and the other two by Light (1921, 1930) from the Philippines. Several species, however, are known from the Nearctic Region.

C. pintoi has been discovered once only at Talawila, near Puttalam (sea level), a naturally arid area with a sparse xerophytic flora. It was found inhabiting a small rather dry, dead tree stump, buried in the sandy soil. The insect had excavated long and narrow galleries in the wood, which was thus extensively riddled. The number of insects in the colony was not very large but all stages, including alates, were collected. Although of special academic interest, this species cannot be regarded as of economic importance at the present time.

Genus **Neotermes** Holmgren

This genus contains two local representatives, both of which are important primary pests of living woody plants in Ceylon. They, in common with most termites, are extremely polyphagous, being associated, according to present records, with at least 43 different food-plants belonging to several Natural Orders. They are familiar in Ceylon as very serious pests of living tea bushes.

The insects do not readily kill the plant they infest, since only the heart-wood is devoured, the sap wood usually remaining unattacked. The plant may survive for many years following the original infestation without any external indication of attack but gradually it is eaten out, a mere shell remaining, which also finally succumbs to the attack. The havoc wrought by *N. militaris* on some tea estates is enormous.

N. greeni Desneux

This species was described in 1907 by Desneux from material collected from tea at Peradeniya (Ceylon).

It excavates an extensive system of moderately large longitudinal galleries in the wood it attacks. Seldom does its attack extend below

ground level. The commonest host-plant of this species is *Grevillea robusta.* Of the 30 known host-plants of this termite, the following are the more important economic trees: *Artocarpus integrifolia* (jak), *Anacardium occidentale* (cashew nut), *Camellia sinensis* (tea), *Hevea brasiliensis* (rubber), *Mangifera indica* (mango), *Michelia champaca* (*sapu*), *Nephelium lappaceum* (*rambutan*) and *Pithecolobium saman* (rain tree).

The insect has a very wide distribution in the island and has been collected from sea level up to about 5,000 feet elevation. Though widely distributed, it is not so destructive as the other local species of this genus.

N. militaris Desneux

This insect has been known as a pest of tea as far back as 1890 (Jepson, 1927) although it was first described by Desneux only in 1904.

It is the most destructive termite of living tea plants in Ceylon. It hollows out the stem and branches of the plant it infests including roots and even rootlets. (Figs. 17, 18). In the case of attacks of long standing, often only an external shell of the plant remains. In addition to tea, it has been found to attack 17 other plants, important of which are the following : *Acacia* sp., *Cedrela toona*, *Crotalaria anagyroides*, *Cinnamonum camphora* (Camphor), *Erythrina lithosperma* (dadap), *Eucalyptus* sp. and *Grevillea robusta.*

The insect chiefly occurs at altitudes of from 3,500 to 4,500 feet. The chief sphere of its activity is the Maskeliya, Lindula and Talawakele districts, but there are a few records of its sporadic occurrence in Dimbula, Watagoda, Pundaluoya, Kadugannawa (1,750 ft.), Madulkele, Rangala and Deniyaya.

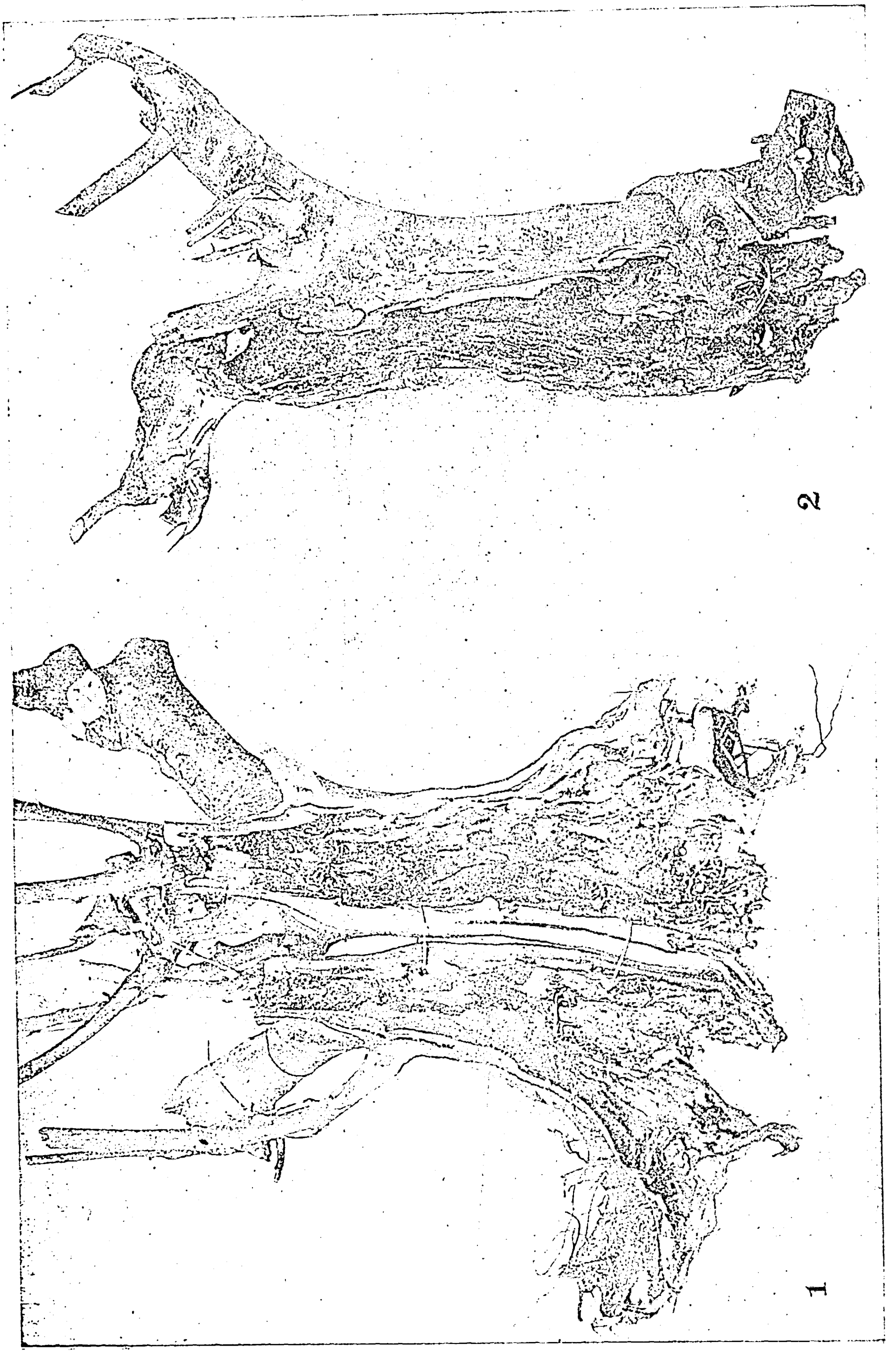
The termites very commonly attack the roots and rootlets of tea bushes and through these they invade adjacent bushes if the roots of sound bushes are in contiguity with the infested ones. The insects also gain entry to tea bushes and other trees in the winged stage through dead snags, wood-rot cavities, etc. It is not unusual to find colonies of from 3,000 to 4,000 individuals in a single tea bush.

N. militaris ab. **unidentatus** Kemner

Kemner (1926) provisionally described this form from a single soldier found among specimens sent to him for determination. Since the duplicate soldiers retained in Ceylon do not differ from *militaris*, the one specimen described may be regarded as a "freak". The specimens were obtained from a tea bush at Bogawantalawa at an altitude of 4,200 feet.

Genus **Cryptotermes** Banks *s. str.*

Six species of *Cryptotermes* have so far been recorded from Ceylon ; five of these have yet to be described.



FIGS. 17—18. Nature of damage by *Neotermes militaris*

Left (1) tea-bush split in half to show typical central cavity; Right (2) tea-bush showing typical injury, one side of the bush collapsed, showing the central cavity. (After Jepson)

Species of the genus *Cryptotermes* nest in dry wood and most of them, on account of the extensive and widespread injury they cause to building woodwork, furniture, etc., are domestic pests of considerable economic importance. They excavate small elongated galleries in the wood they inhabit and their presence would not be suspected but for the accumulation of the expelled fæcal pellets beneath the wood they infest. They prefer soft to hard wood.

The members of a colony of *Cryptotermes* are usually small in number but it is not uncommon to find several distinct colonies in a single small piece of wood and even two different species in close proximity to each other. The soldiers of these species are very characteristic, having dark heads truncated in front and sometimes referred to as being of "bull dog" shape (Figs. 19-28). Their number in a colony is usually very small, more so than in the other genera.

The insects have a very wide distribution in Ceylon from sea level to nearly 6,000 feet, but they are most commonly met with at elevations below 3,000 feet.

C. perforans Kemner

C. perforans, which Kemner described in 1932, is the commonest member of this genus. It is very prevalent at altitudes below 2,000 feet but search at higher altitudes is almost certain to reveal its presence there. It has usually been collected from dressed timber, but on one occasion a wingless imago and a few larvæ were collected from a dead branch of *Eugenia jambolana* (*ma-dan*) at Talawila, near Puttalam.

C. angulatus Kemner (MS)*

There is only a single record of this species collected from the woodwork of a tea factory at Balangoda about 1,500 feet above sea level.

C. brachygnathus Kemner (MS)*

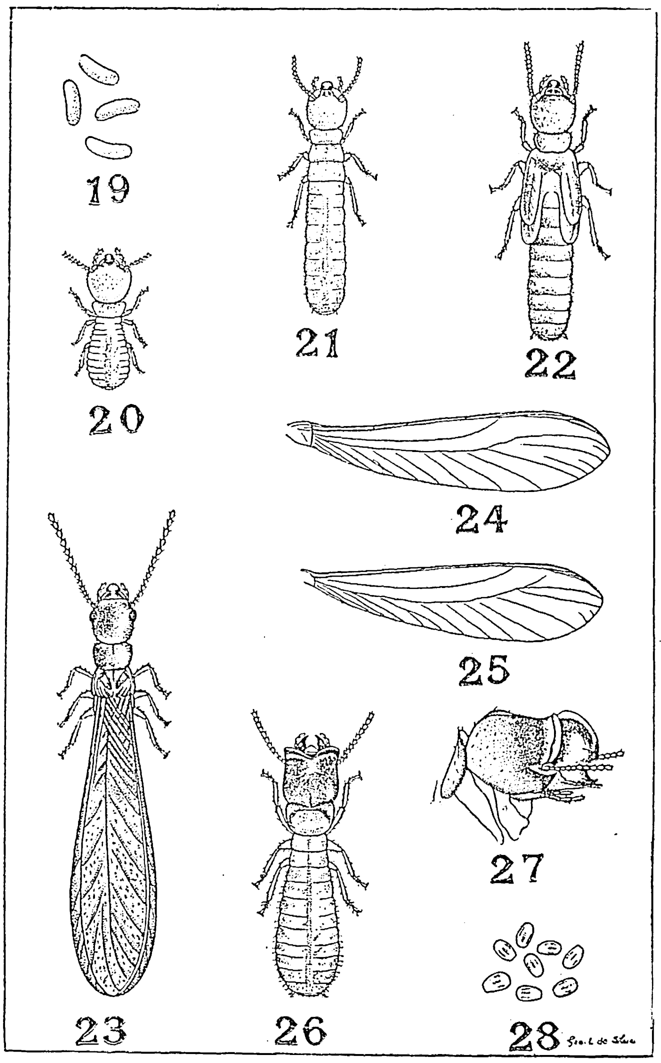
This species was obtained at Talawila from *Mimusops hexandra* (*palu*) the wood of which is very hard. The winged adults had gained entry through a dead and dry snag of the tree. The insects were mostly confined to the dead wood although a few were observed to have penetrated to the living tissue.

C. ceylonicus Kemner (MS)*

Specimens of this termite have been collected from living trees and sawn timber. At Peradeniya (elevation 1,500 ft.) it was found (including

* Descriptions of Kemner's species referred to here have not yet been published and my notes are in no way intended to establish the specific names.

alates) in *Ficus altissima* in both dead and live wood. *Diospyros insignis* (*gona*) was found to harbour the insects at Chilaw (sea level). They were mostly found in a dead and dry snag but some were feeding on live wood. At Paiyagala, near Kalutara, a single imago was obtained from sawn timber.



FIGS. 19—28. *Cryptotermes* sp.

19. eggs; **20.** young larva; **21.** full-grown larva; **22.** nymph with long wing-pads; **23.** winged adult; **24.** right fore-wing of adult; **25.** right hindwing of adult; **26.** soldier; **27.** head of soldier in profile; **28.** fæcal pellets. (After Jepson)

C. **lignarius** Kemner (MS)

This species has been taken only once when a winged adult was attracted to lamplight at Hakgala at an elevation of 5,700 feet. It is evidently a rare species.

C. **tectus** Kemner (MS)

This species has been collected on two occasions in Colombo (sea level) infesting a *Doona zeylanica* (*dun*) beam and venesta boards. Soldiers as well as alates of this species have been collected.

Subgenus **Planocryptotermes** Light

Light (1921) erected the genus *Planocryptotermes* for the reception of the Philippine species *nocens*. Later (1930), after further study he, however, considered this to be of subgeneric status only. The subgenus is represented in Ceylon by a single species, *C. primus* (Kemner), described in 1932. Light (1937a) regards this species, together with his species *nocens*, to be synonymous with *C.* (*Planocryptotermes*) *dudleyi* (Banks).

C. primus is the commonest and hence the most destructive dry-wood-nesting termite in the island. It has been recorded at altitudes varying from sea level to 5,700 feet, but it is apparently more prevalent at elevations below 2,000 feet. Its habits are typical of those of species of *Cryptotermes* and it is the largest of the local dry-wood-nesting termites.

The number of individuals in a well-established colony is somewhat larger than in colonies of other Ceylonese dry-wood-nesting termites. It may be of interest to record that in a piece of *Melia dubia*, (*lunumidella*) timber 24″ x 6″ x 1″, which was riddled by these insects, 1,662 larvæ and nymphs, 12 soldiers, 7 winged adults, 181 eggs and a deälated pair were present. As the number of individuals in a colony is not usually so great, it is not possible to state that the individuals in this colony were the progeny of the single deälated pair. It is not uncommon to encounter several colonies very close to each other in a small piece of timber.

Genus **Glyptotermes** Froggatt

The habits of the species of Ceylonese *Glyptotermes* are very similar to those of *Neotermes greeni* referred to earlier. They attack dead and living plant tissue and one species, *G. dilatatus*, is a well known pest of tea in the island. Four species and one variety of this genus are known in Ceylon, of which the variety is yet to be described.

G. ceylonicus Holmgren

This termite was originally described from specimens collected at Peradeniya from decaying logs and branches (Holmgren 1911b). It is evidently not a common species. It has been recorded as infesting a decayed log and a diseased *Hevea* (rubber) tree at Peradeniya (1,500 ft.) a *Hevea* tree at Passara (2,500 ft.) and an *Acacia* at Hewaheta (2,000 ft.). The damage it causes takes the form of an extensive system of longitudinal galleries which are confined to the stems and branches of the attacked trees.

FIG. 29. Tea-bush sawn into two to show the nature of damage by *Glyptotermes dilatatus*. (After Jepson)

G. ceylonicus var. **cylindricus** Kemner (MS)

Only a single record of this form is available. The colony was found at Elpitiya (about 500 ft.), severely infesting a dead *Hevea* tree.

G. dilatatus Bugnion & Popff

The original description of this species by Bugnion and Popoff (1910) was based on specimens collected on tea at Ambalangoda. It excavates longitudinal galleries smaller than those constructed by *Neotermes greeni*. They "form a network of communicating tunnels giving the wood, in longitudinal section, a honey-combed appearance" (Fig. 29.). The attack rarely extends to the roots. In addition to tea, of which it is a very important pest at mid-elevations, the termite has been found to injure 15 other plants : *Artocarpus integrifolia* (jak), *Coffea robusta* (coffee), *Erythrina lithosperma* (dadap), *Caryophyllus aromaticus* (clove), *Hevea brasiliensis* (rubber), *Moringa oleifera* (*murunga*) and *Theobroma cacao* (cacao).

The distribution of the insect is restricted to elevations below 2,000 feet. As a pest of tea it is most commonly found in the Kelani Valley district. From an economic standpoint, *G. dilatatus* is the most important of the local *Glyptotermes* species.

G. jepsoni Kemner

This is a characteristic species, recently described by Kemner (1932), the distribution of which, so far as present records go, is restricted to Maskeliya and Pundaluoya (elevation 3-4,000 feet).

Like other species of *Glyptotermes* it hollows out longitudinal galleries in the wood it infests. It shows a partiality for dead and decaying wood but living tissue is not neglected. It has been found infesting unidentified jungle tree stumps, those of *Doona zeylanica* (*dun*), and also dead and live wood of *Albizzia* species, *Cedrela toona* (*toona*) and *Syzygium gardneri*. It has not been found attacking cultivated crops and is not of economic interest at the moment. The attack is usually confined to portions above ground but in one instance the insects were found in a tree stump below ground level.

G. minutus Kemner

This species was described by Kemner in 1932. It has been collected on two occasions only at Peradeniya (1,500 ft.). In one case, the small insects were tunnelling small galleries in the dead wood of a branch of *Pithecolobium saman* (rain-tree). In the other instance, the insects

were found attacking sound wood of a *Cupressus knightiana*, an ornamental conifer. The winged form of this species is at present unknown.

V. THE BIOLOGY OF THE CASTES OF CALOTERMITIDAE

In spite of the very extensive and valuable contributions which have been made, by many talented and distinguished workers, to our knowledge of the biology of termites, much remains to be known. The habits of termites are such as to render it almost impossible to follow accurately the ontogeny of an individual to the adult state, for when removed from its fellow members it fails to survive. Even the eggs, which are often licked and transferred hither and thither in the nest by the insects, do not hatch when isolated. The complex social life of termites, with its polymorphic types and their varied behaviour and occurrence under different conditions, present many biological problems which are at present little understood. It is probable that if the habits and social organization of these most interesting insects were better known, the primitive termite would be regarded as the most interesting member of the insect world—more interesting even than the much studied and highly specialized ant or bee.

Breeding of Calotermitidæ

The chief difficulty in the study of termites has been to maintain them alive in the laboratory for long periods in such a way as to render regular observation possible. Other investigators (Haviland and Sharp, 1896; Grassi and Sandias, 1893-94; Bugnion and Ferrière, 1911; Snyder 1915, Imms, 1919 and Kalshoven, 1930) have kept these insects alive in captivity for fairly long periods, but their methods were not quite suitable for the breeding of species of *Neotermes* and *Glyptotermes*. After repeated attempts, a technique was devised by Jepson which made it possible to rear these termites with ease and to keep them alive for indefinite periods. The dry-wood-nesting species can easily be reared in glass tubes provided with a supply of their food material. These methods are briefly described below:

Breeding of moist-wood-nesting termites.—In the breeding of these termites, it was found that an essential factor was the regulation of moisture admitted to the breeding medium.

In the earlier experiments the bottom of a large test tube was drawn out and the capillary tube so formed carefully snapped off leaving a small aperture. The basal inch of the tube, including the capillary portion, was then packed fairly tightly with absorbent cotton-wool. The rest of the tube, to within one inch of the top, was filled with firmly packed and moistened Sawdust of the wood of the host-plant of the particular species of termite which was being reared. A hole, 1/16th inch in diameter

and one inch deep, was then formed with a fine rod in the packed sawdust alongside the inner surface of the tube. The insects from which it was decided to breed were then allowed to enter the hole and the tube was finally plugged with a cotton-wool, care being taken to keep the cotton-wool clear from the top surface of the packed sawdust.

It was later found more convenient and equally efficient to employ large-sized adapters (straight form) in place of test tubes.

The tube, or adapter, is placed in a glass beaker containing a small quantity of water, the level of which depends upon the length of the capillary portion. The aim is to allow the cotton-wool to absorb the required amount of moisture from the containing vessel, without making the sawdust too moist. The level of the water should be maintained by additions as required and under no circumstances should the water be allowed to evaporate completely. Where several tubes are in use they may be placed in test tube racks with the capillary ends in shallow troughs of water. The tubes should be kept in a dark place as this allows the developing colonies to work freely in the sawdust medium against the inner surface of the glass container where they can be observed. If kept in the light, the insects work in the centre of their food supply where they cannot be watched.

The less disturbance the insects receive the better, and the sawdust should not be probed or otherwise moved. If fresh food is required it should be added carefully, so as to cause no damage to the insects.

If the insects also feed on the cotton-wool, as they sometimes do, further supplies can be re-introduced in very small quantities through the capillary ends but this operation requires some skill and patience. If necessary, the insects can be induced to migrate from their original home to another prepared tube. This operation, again, requires patience and some careful manipulation.

Observations can be made daily, the tubes being removed from their darkened chamber one at a time and replaced as soon as possible.

Several insects have been carried through their entire development in the manner described above.

Breeding of dry-wood-nesting termites:—This is a simple undertaking compared with the above method although in some cases observation is not so easy. The insects can be isolated in tubes with their food and observations can be regularly made. If winged adults are to be used for breeding, it is sufficient to bore a small hole in the selected wood, which should preferably be of the plant normally favoured by the insects under study. The pair should be introduced into the hole and the block of wood placed in a tube, plugged with cotton-wool. Even when immature forms are to be used for observation, a hole may be bored in the wood with

advantage. This can be covered with a small piece of cardboard which the insects soon seal to the wood. For observational purposes it is necessary, in the early stages, to remove this cover and replace it.

When the developing colonies need further food this may be introduced into the tube as, and when, necessary. No moisture is required.

These insects can also be bred in tubes with filter paper as food, instead of wood, but where this is done it is advisable occasionally to add small pieces of wood to this diet. The insects will also feed on cotton-wool.

The castes of Calotermitidæ

It has already been mentioned that in a termite society, as in the communities of other social insects, there are several adult types or castes within the same species which exhibit not only morphological but also functional differences. Some of these castes are capable of reproduction while others are sterile. In the Calotermitidæ, there is but one sterile caste and that is the soldier. A true worker caste, which is considered to exist in other termite families, is absent. Of the reproductive castes, neoteinics, which appear only under certain circumstances, exhibit practically no morphological differences from the larvæ and nymphs which give rise to them, except in colour and loss of abdominal styli in the female. These, therefore, may not be considered true castes in a restricted sense although they are physiologically different from the immature form. They are, however, considered by several workers as distinct morphological castes (Thompson and Snyder, 1920).

The following forms comprise the castes of the Calotermitidæ :

Macropterous form.—These are the winged reproductive adults or alates which found colonies. The deälated males and females are usually called true kings and queens. They have a dark chitinous body with well developed eyes and reproductive organs. These are sometimes referred to as adults of the first form (Thompson, 1917).

Neoteinics.—(*a*) Brachypterous form : These, together with the apterous reproductive forms, are often called neoteinics, supplementary, substitute or complementary kings and queens. The brachypterous adults have short wing-pads of varying size. Their eyes, and perhaps the reproductive organs also, are less developed than in the macropterous form. In *Neotermes* and *Glyptotermes* they are of a brown colour and are readily singled out, while in *Cryptotermes* they are less conspicuous, being of a straw-yellow colour and less pigmented. Experience is needed in order to distinguish the apterous forms from nymphs and larvæ. In the neoteinic forms of *Cryptotermes* and *Planocryptotermes* a correlation of degree of coloration exists with the age of the immature forms. The brachypterous adults are sometimes called reproductive adults of the second form.

(*b*) Apterous form : These wingless reproductive forms, sometimes known as "ergatoid" kings and queens or reproductive adults of the third form, are of the same colour as the preceding type. In *Cryptotermes* and *Planocryptotermes*, however, they are sometimes less conspicuous, being only slightly pigmented. Their eyes are entirely absent or much reduced, being represented sometimes by traces only. The reproductive organs are not so well developed as in other fertile forms.

Soldiers.—In this highly specialized and distinct sterile caste, which comprises both male and female individuals, the reproductive organs are non-functional and the eyes absent or vestigial except in some genera. The insects are wingless, but very occasionally soldiers with wing pads may be met with. They are large-headed with prominent serrated mandibles. The usual colour of the chitinized head is chestnut brown. In species of *Cryptoterms* the head is darker and more truncated anteriorly than in the case of species of other genera of termites.

Immature forms.—It is from these that the forms mentioned above arise and, therefore, they do not constitute a separate caste although they represent, functionally, the worker caste of other families.

The development of Calotermitidæ

As has been stated earlier, it is extremely difficult to follow with accuracy the prolonged development of individual termites especially as, at one stage or other, they all resemble one another in appearance. Further, their complex life and behaviour, which vary according to the needs of the colony, further complicate the problem. In spite of these difficulties, much information has been accumulated, both in the field and laboratory, to enable a general idea to be formed of the development of some species of the Ceylon Calotermitidæ. In all essential particulars, the development is the same.

Eggs.—The small eggs of the species of Calotermitidæ are creamy-white in colour, with a pinkish tinge when fresh, slightly reniform in shape and are laid singly throughout the year. They are found in small clusters in different parts of the nest, usually the centre. The number of eggs found in a nest at one time is, normally, small. The female may lay one or two eggs a day or may allow several days to elapse without oviposition, in this respect differing from the less primitive termites, which are capable of producing several thousands of eggs a day. The eggs are licked and tended by the parents and also by the immature forms carrying them in their mouths to favourable situations in the nest. The incubation period varies from $1\frac{1}{2}$ to 2 months.

Larvæ and nymphs.—The young termites, shortly after hatching, are active and pure white in colour. They cannot feed themselves in early life

and are fed by the elders with regurgitated food. The colour of the young insects grows darker after they have commenced to feed. The development of the young is extremely slow and several ecdyses are passed through before the adult condition is attained.

Termites undergo an incomplete metamorphosis. The young of insects with such metamorphosis are generally referred to as nymphs but, among termites, according to such authorities as Lespès, Hagen, Grassi and Sandias and other more recent workers, the term is restricted to individuals having wing-rudiments easily visible to the naked eye. In the present paper, the term nymph is used to denote individuals possessing wing pads, visible either to the naked eye or under magnification. The young without visible wing pads are referred to as larvæ.

About 7 to 10 days before moulting, a larva or nymph turns in colour to a dull white and loses its abdominal markings. Immediately prior to moulting it becomes somewhat inactive. After the moult is completed the insect is pure white in colour with thin chitin and soft brownish mandibles, the integument hardening after a short interval. The exuviæ are devoured by other members of the colony.

It has not been possible to ascertain definitely the number of instars of an individual of any caste. Grassi and Sandias (1893-94) state that there are four moults in the development of asexual forms and five in sexual forms of *Leucotermes lucifugus* Rossi, while Imms (1919) believes that in *Archotermopsis wroughtoni* Desn. there are at least four moults, excluding the final change to the adult, during the whole period of growth. Heath and Wilbur (1927) state that the young of *Zootermopsis nevadensis* Hag. and Z. *angusticollis* Hag., undergo seven moults before reaching the winged stage. Light (in Kofoid *et al.*, 1934) also refers to seven instars in the development of winged adults of *Zootermopsis*. Kalshoven (1930), in his study of *Neotermes tectonæ* Damm., also believes that there are seven instars in the development of the winged form.

The writer's observations on the Ceylonese Calotermitidæ indicate that the number of moults is variable and may be more than is generally believed. Harvey (in Kofoid *et al.*, 1934) refers to the occurence in *Calotermes minor* Hag. of from one to three "interpolated" moults during the last three of the seven instars. These moults do not noticeably modify the size and the structural characteristics of the insect. Local observations corroborate the statement, except as regards the number of moults which may vary considerably in the more advanced larval and nymphal stages. It should be mentioned, however, that there are, normally, three ecdyses between the appearance of the wing rudiments and the final winged state, a fact which does not seem to have been recognised by some authorities. Further reference will be mad e to this fact later.

A larva may become full grown in about eighteen months to two years, but this period may vary. When the larva is full grown and is to proceed eventually to the winged stage, it moults into a nymph with rudiments of wing-pads, which in termites of small size, are almost invisible to the naked eye, but are readily seen under magnification. This nymph is of the same size as a full-grown larva. Kalshoven (1930) also refers to these appendages but, apparently, he does not consider them to be wing-pads as he states "they give the impression of wing-stubs". The insect usually remains in this instar for a few months. During the latter period of the instar a very slight elongation of the wing-pads may be noticeable. At the next moult short wing-pads appear, which also later increase slightly in length. There is very little, or no increase in size of the body during these instars.

Then follows the penultimate instar in which long and prominent wing pads are developed, becoming markedly inflated and creamy-white in colour with age. The eyes at this stage become more prominent and resemble those of the perfect insect. At this stage, the insect is creamy-white in colour and larger in size than the other nymphs. The final ecdysis gives rise to the adult insect, the white wings of which shortly afterwards assume their normal colour. At this moult, the genital appendices of the female disappear, thus enabling the sexes to be distinguished easily.

Each nymphal instar may occupy four months or more but the periods are extremely variable. In *Neotermes militaris*, the nymphal period in the case of two colonies bred in captivity occupied two and a half and three and a half years, respectively.

The development of nymphs with short wing-pads, after moulting, into nymphs with long wing-pads has, apparently, not been observed by some investigators. Snyder (1915, 1935) and Thompson and Snyder (1920) consider that there are two forms of nymphs : one, the 'primary form', with elongate wing-pads which develops into the winged form, and the other, 'second form', with short wing-pads, which is the prototype of the brachypterous reproductive adults. The writer does not agree with this observation. He has repeatedly noted that nymphs with short wing pads moult into nymphs with long wing-pads, thus confirming the opinion of Kalshoven (1930) on this subject. The nymphs with short wing-pads do not ordinarily change into brachypterous adults, as some authorities believe, except under certain conditions which will be referred to later in this paper.

Arrestation of larval and nymphal development.—The development of termites is controlled to an important degree by the constitution of the colony. The insects have complete control over their development. Laboratory observations reveal that a full-grown larva may prolong the larval condition, without developing wing-pads, for a very long period.

This accounts for the large proportion of full-grown larvæ generally found in a colony. The arrest of further development is possible not only in this stage but also in the subsequent nymphal stages. This important fact does not appear to have been observed, or at any rate to have been sufficiently emphasized, by other investigators but it has been confirmed by the writer by repeated observation and can be readily demonstrated. Kalshoven (1930) is also of opinion that larvæ can remain stationary in their development and Bugnion and Popoff (1910) believed that it was possible for one section of the larvæ to persist in their neutral (asexual) state, thus representing a worker caste in process of formation.

A nymph, well advanced towards a moult, has no functional ability to stop its development to the next instar. A period of not less than six weeks prior to moulting is needed for a nymph with long pads to retard change into the winged form, and this period is much less in the other two nymphal stages. Thus, a nymph with long wing-pads, the prototype of the macropterous form may, if necessary, remain in the immature condition for a very long period inhibiting the development of the gonads, eyes or wings according to the needs and circumstances of the colony. This observation justifies the conclusion that the production of the adult castes is subject to regulation, being hastened or retarded as occasion demands.

The development and occurrence of macropterous forms.—The process of development of the winged adult has been indicated above. It has been indicated, furthermore, that termites can regulate their development in response to the requirements of the colony. It is not, therefore, easy to determine the duration of the immature stage of any caste. For this reason the life-cycle period is very variable. For example, winged adults of *Cryptotermes* (*Planocryptotermes*) *primus* (Kemner), were obtained in one artificial colony, raised from eggs laid by neoteinics, in two years and seven months, while in two colonies produced from eggs laid by winged pairs and two other colonies raised from neoteinics they appeared after six years. In other colonies, winged adults were produced in four years and eleven months and five and a half years, respectively. In a colony of *Cryptotermes perforans* Kemner, winged forms appeared in five years. Winged adults have also been obtained in an artificial colony of *Neotermes militaris* in eight and a half years and in another in seven and a half years. *Glyptotermes dilatatus*, in a colony raised in the laboratory from neoteinic adults, produced winged forms in four and a half years.

Observation both in the field and the laboratory appears to indicate that when the larvæ are fully grown, the factors which determine their development into the nymphal and, finally, to the winged adult stage are overcrowding, shortage of food and other unfavourable conditions.

When the full numerical strength of a colony has been reached, the overcrowding is relieved by the excess population developing wings and leaving the colony. A well-established colony of *Neotermes* or *Glyptotermes* may contain a population of from 2,000 to 3,000 individuals or more, while the number in a colony of *Cryptotermes* is very much less. Winged adults of *N. militaris* have often been observed in tea bushes in which a curtailment of food was threatened owing to their having been so excavated as to be reduced to mere shell. Unfavourable conditions, such as excessive dampness or drying out of the wood or a change in the food medium, may also favour the development of winged forms.

The number of winged individuals produced in species of Calotermitidæ is extremely small compared with species of Rhinotermitidæ and Termitidæ, where thousands of winged forms are produced before each swarm. In artificial colonies, the number of alates which develop is small, normally ranging from 20 to 50 although the number may sometimes be less. In Calotermitidæ, the winged adults do not swarm simultaneously but at irregular intervals. Swarming extends over a number of days, only a few insects emerging daily. The imagines remain in the nest before emergence for from 3 to 4 weeks. A further 9 to 14 days may elapse before the female deposits her first egg.

Development of neoteinics, or brachypterous and apterous reproductive forms.—Some useful information has been obtained concerning these forms of which, as indicated by Imms (1930) and Snyder (1935), very little is known at present. Grassi and Sandias (1893-94) have stated in their admirable and much-quoted work on these insects that these forms are substitutes for the true royalties. They have also referred to the development and occurrence of these types in natural and artificial colonies. But, many distinguished modern workers have found it difficult to agree with their conclusions, mainly in regard to the origin of these forms. Observations on, and experiments with, the local Calotermitidæ lend general support to the conclusions of Grassi and Sandias, although accumulated evidence has somewhat broadened and modified them.

In the course of the writer's observations, a large number of colonies of species of *Neotermes*, *Glyptotermes*, *Cryptotermes* and *Planocryptotermes* has been examined and in no instance have neoteinics been discovered associated with a pair of functioning deälated adults. This observation agrees with those made by Grassi and Sandias (1893-94), Heath (1927) and Kalshoven (1930). So long as the winged adults are capable of functioning in a colony, there is no need for neoteinics and, in fact, they are not produced. Should one or both of them die or a few immature members be cut off from the main colony, supplementaries are then produced in a comparatively short space of time from these young stages. The researches of several investigators including Kalshoven (1930), Castle, Pickens, and

Harvey (in Kofoid, *et al.*, 1934) on various species of termites also show that neoteinics are produced within a short time if groups of larvæ and nymphs are isolated from the functioning reproductive adults.

Again, in no case have brachypterous forms been observed in young colonies containing only larvæ and soldiers, although apterous forms have not been uncommon. But in older colonies where nymphs have been present, brachypterous as well as apterous adults have been found. These observations are significant, particularly in connection with the production of these forms in the laboratory as described below.

The above observations, in particular the fact that neoteinics are rapidly produced when a few larvæ or nymphs are cut off from the parental nest, indicated that it should be possible, if these forms are not pre-determined, to raise them without difficulty in artificial colonies in the laboratory by the isolation of a few immature forms. This has been done in a very large number of experiments by random selection and isolation in tubes of larvæ or nymphs of various stages. As a result of these experiments it has been found that it is a simple matter to raise neoteinics in the laboratory, provided the breeding medium is satisfactory. This applies particularly to *Neotermes* and *Cryptotermes* which should, in addition to food, have a properly regulated moisture supply.

In these experiments, not only have numerous apterous reproductive forms been raised, by isolating two or more larvæ, but also brachypterous adults with wing-pads of various sizes. Indeed, brachypterous adults with long wing pads have but rarely been encountered in nature, yet they have been readily raised in the laboratory by isolating nymphs with long wing-pads which, otherwise, would normally develop into alates. Such nymphs cannot, however, arrest their development and change into neoteinics, in spite of the demands of the situation, if they are far advanced in this instar. In such a case, they cannot avoid developing into winged individuals, leaving the temporary nest as they would normally do in nature. But if the nymphs are isolated about 8 weeks before their normal development into alates, they can then inhibit the development of wings and change into neoteinics or remain in the nymphal condition with the neoteinics. Once the wings are developed, the winged insects leave the nest even if it possesses no egg-laying adults.

If nymphs with short, or rudimentary, wing-pads are isolated they will change into brachypterous adults with short or rudimentary wing-pads, respectively. But if they are far advanced in the nymphal instar, they will moult to the next instar and may later develop into neoteinics. Thus, a nymph with short wing-pads, if separated about a week before the moult, will develop into a nymph with long wing-pads and later into a neoteinic if the requirements of the colony so demand.

It may be mentioned that in some instances, when a nymph moults into a brachypterous adult, there occurs, as Grassi and Sandias have observed, a reduction in size of the wing-pads. It has, indeed, been observed by the writer that this reduction may accompany each moult until the wing-pads are completely suppressed in the case of a nymph which does not, in response to a changed situation, continue to proceed to the winged state. Surprising as this phenomenon may appear it appears to be true, but further experiments are in progress definitely to establish this observation.

When a few larvæ or nymphs are isolated they commence to found a new colony. Some of them moult into neoteinics, while the others remain in the immature condition. One or two, depending on the number available, may develop into soldiers. Neoteinics may appear within a week of isolation but the period may extend to 3 or 4 months depending on the preparedness of the insects to moult. Nymphs with long wing pads generally take from 3 to 4 weeks to moult after being isolated. After the moult, growth is manifested externally by a change in colour and also in the female by the loss of the abdominal styli. The sexes are not produced in equal numbers although, sometimes, a pair alone may develop. A peroid of from two or five weeks elapses after the change of the female to the neoteinic state before oviposition takes place.

Kalshoven (1930), in his useful contribution to this subject, states that when a few larvæ or nymphs of *Neotermes tectonæ* are isolated, some that are to change into neoteinics are devoured by those which are not to undergo this change and, further, that only one or two individuals are finally left, no new members of the colony being produced. Similar experiments with Ceylonese Calotermitidæ do not support these observations. Kalshoven was unable to obtain evidence that neoteinic formation was brought about by an ecdysis nor was he able to witness nymphs with long wing-pads developing into neoteinics as observed by Grassi and Sandias in the case of *Calotermes flavicollis*. Observations by the writer on Ceylonese Calotermitidæ conclusively prove that larvæ or nymphs moult prior to the change to the neoteinic state and that nymphs with long wing-pads can change into brachypterous adults provided they are not too advanced in development in that instar.

Heath (1927) believes that in *Zootermopsis*, neoteinics develop principally from soldier larvæ or nymphs. This view that apterous and brachypterous reproductive adults are merely sexually mature soldier larvæ or nymphs is not in accord with the observations made in Ceylon.

According to field observations on Calotermitidæ in Ceylon, full-grown larvæ, or occasionally nymphs with short or rudimentary wing-pads, are selected for development into neoteinics. But the fact that even younger individuals can hasten their sexual development, if occasion so demands,

can be demonstrated by isolating a few young or half-grown larvæ. Neoteinics produced in this manner would, of course, be smaller in size than normal. Apterous neoteinics, for example, were raised in artificial colonies of *Neotermes militaris* and *Glyptotermes dilatatus* from larvæ which were only about nine months old.

Neoteinics occur very commonly in colonies of *N. militaris*. They are also not unusual in *Glyptotermes* colonies. In a tea bush harbouring one colony of *N. militaris* the number of neoteinics present is usually fairly large. Occasionally one may find as many as one hundred. In colonies of *Glyptotermes dilatatus* the average number is somewhat less, while in colonies of *Cryptotermes* and *Planocryptotermes* it is customary to find only a few, occasionally only a single pair. Neoteinics are generally found congregated together in the same part of the nest as has been observed by Haviland (1898). If the number is great, they may be found in batches of from 10 to 20, together with larvæ and nymphs, in various parts of the nest.

Grassi and Sandias (1893-94) and Kalshoven (1930) state that in orphaned colonies of *Calotermes flavicollis* and *Neotermes tectonæ*, respectively, only two neoteinics are produced to replace the original pair, while Heath (1931) found several in colonies of *Zootermopsis* as did Haviland (1897) with certain Oriental species. In the Ceylonese Calotermitidæ, as has been mentioned above, several neoteinics have been ovserved in each colony in the field, particularly those of *Neotermes* and *Glyptotermes*, and this has been confirmed in the laboratory where it has been found that when a number of larvæ or nymphs are isolated, several neoteinics are produced and not only a single pair. Kofoid (Kofoid *et al.*, 1934) has also stated that several male and female neoteinics are produced at the same time in detached colonies in exceptional cases. Pickens records in the same publication that in *Reticulitermes hesperus* as many as three queens may develop in the same cavity. Harvey (*op. cit.*) obtained neoteinics of *Calotermes minor* by isolating small groups of 20 to 30 older nymphs. Two of them, he records, may develop into a reproductive pair but sometimes three or four reproductive forms may appear.

In colonies of *Neotermes* and *Glyptotermes*, the sexes of neoteinics are rarely represented equally. Usually there is a marked excess of one sex. Similar observations have been made in the laboratory when neoteinics were raised from larvæ or nymphs. Haviland (1898), in his study of the termites of the Malaysia, believes that "neoteinic queens are often consortless and in many cases wholly absent". It is known, however, that males are always present with the females. Snyder (1935) states that neoteinics are polygamous, there being usually a few males with many females. This, however, is not always so.

The number of eggs laid by a neoteinic female is generally less than a deälated adult, but this is counterbalanced by the large number of neoteinic females usually present in a colony.

From the eggs laid by neoteinics, whether brachypterous or apterous, all other castes can arise. Snyder (1926, 1935) and Imms (1931), who relies on the works of Snyder and Thompson, believe that macropterous forms do not develop from such eggs and that not even brachypterous forms can develop from eggs laid by the apterous form. In other words, they believe that these forms breed true to type. But that this is not so has been definitely proved in artificial colonies founded by neoteinics of *Glyptotermes dilatatus* and *Cryptotermes* (*Planocryptotermes*) *primus* which eventually produced the macropterous form.

Nothing is known of the progeny resulting from the union of a macropterous adult with a different reproductive form (Snyder, 1926). In the Ceylonese experiments it has been ascertained that the progeny of a deälated male and an apterous female is, in all respects, similar to that of a winged pair. A colony of *Cryptotermes perforans* raised by such a pair produced winged adults in a period of 4 years and 10 months.

It has also been stated that neoteinics are fed by larvæ or nymphs and are unable to live without their association (Thompson and Snyder, 1920 ; Snyder, 1935). In Ceylon, neoteinics have been observed to feed themselves not only on wood but also on the exuviæ of other members. They have, however, never been found alone in nests under natural conditions and when isolated without the company of the immature forms they generally die. But several neoteinics of *Neotermes militaris* and *Glyptotermes dilatatus* have been kept alive without larvæ for long periods and although they sometimes laid eggs these failed to hatch. Several neoteinics, in one instance, were successfully isolated in confinement for one year and eight months, thus dispelling the belief that neoteinics cannot feed themselves and that the care of the immature stages is essential for their existence.

Snyder (1926, 1935) states that in well-established colonies of *Reticulitermes* in the United States of America large number of nymphs of brachypterous and apterous reproductive forms appear seasonally each year and that they mature at the same time as do the macropterous adults. This is not in accord with observations made in Ceylon, nor does the fact appear to have been established for other termites by other workers. There is, thus, no evidence forthcoming to prove the regular seasonal occurrence of neoteinics in each colony. Indeed, it is impossible to differentiate, according to observations made in Ceylon, which larvæ and nymphs in a colony will turn into neoteinics and which will be the future winged adults, as Snyder believes possible.

Snyder (*loc. cit.*) also observes that "just before the flight of the winged adults, these brachypterous and apterous reproductive adults disappear

from parent colonies" and that nothing is known as to what happens to them, whether they are killed by the workers or whether they migrate to form new colonies. It may be possible that these so-called nymphs of apterous and brachypterous adults do not attain the adult condition and then disappear, as supposed, but moult and eventually develop into the winged condition. This may, perhaps, account for the absence of the nymphs or the anticipated brachypterous adults at the time of the flight. It has already been pointed out that nymphs with short wing-pads, from which brachypterous adults could arise, normally moult into nymphs with long wing-pads and that these subsequently develop into the macropterous form.

Development of soldiers.—The proportion of soldiers to the total number of other castes of a termite community is small. They occur fairly commonly in colonies of Calotermitidæ, although their number is less numerous in colonies of dry-wood-nesting termites than in others.

In a few instances, brachypterous soldiers with short wing-pads have been encountered in colonies of *Neotermes militaris*. In these exceptional cases it has always been observed that the colonies were old and contained nymphs in addition to larvæ. Similar soldiers are known to occur in species of *Zootermopsis* and *Calotermes* (Snyder, 1926 ; Light, 1921 ; Heath, 1927).

While soldiers in the Calotermitidæ normally develop from full-grown larvæ, small soldiers, about one third to half the size of the normal soldier, may be produced from small larvæ in incipient colonies. The age of such larvæ may be three months, while that of a full-grown larva may be two years or more. The occurrence of small soldiers in incipient colonies has been recorded by several investigators.

Snyder (1926) has suggested that such small soldiers are produced in young colonies as a result of an insufficiency of food, or possibly of its nature, or to the care that such larvæ receive before they are full-grown and ready to transform into soldiers. This is the case with ants, the larvæ of which are dependent upon such nutrition as the mother is able to provide, but in termites there is no such dependence, the larvæ being capable of feeding themselves and there should, therefore, be no lack of either the quantity or quality of nutrition. The explanation of the occurrence of small soldiers in incipient colonies appears to be that small larvæ, before they have time to develop to their full size, are utilized for development into soldiers owing to the need and circumstances of the colony. When several full-grown larvæ are available, they are preferred to the smaller ones. It has been mentioned earlier that small neoteinics can also be similarly produced by isolating small larvæ.

The factors governing the production of soldiers in artificial colonies has not yet been fully determined. Observations, however, indicate that

not only larvæ of various sizes but even nymphs with long wing-pads can develop into soldiers thus suggesting, although not conclusively at present, that this caste, like the neoteinics, is not predetermined as some authorities maintain. When nymphs of *Glyptotermes*, *Cryptotermes* and *Planocryptotermes* with wing-pads develop into soldiers, their wing-buds are absorbed, while in *Neotermes militaris* they persist, although a small reduction is usually noticeable. Almost similar observations have been made by Grassi and Sandias (1893-94) and Kalshoven (1930).

Before a soldier develops, a larva (or a nymph), not externally different from others, moults into a larval soldier having long, non-chitinized mandibles and a soldier-like head covered by a white, tough cuticle. The body is also white in colour. This instar occupies about three weeks after which the pigmentless larval soldier undergoes a further moult to the adult form.

Heath (1927, 1931) and Heath and Wilbur (1927) believe that in *Zootermopsis* colonies, only the soldier caste develops during the first three or four years. The writer's observations on Ceylonese Calotermitidæ do not support this opinion nor do those made in Java by Kalshoven (1930).

Establishment of colonies

It has been mentioned that colonies of termites are normally founded by winged pairs after deälation. These leave the parental nest at different seasons of the year. Having selected a suitable site, such as the dead or decaying part of a tree, a wound or cavity or a crevice in dressed timber, a pair of the Calotermitidæ will gain entry and excavate for themselves a nest-cell. This entrance is rapidly sealed over with pieces of wood and excretory matter and the enclosed pair begin to form a colony.

It was originally believed that if a colony was orphaned by the death or removal of the "queen" (or the "king"), the colony could not survive. This belief is not now entertained owing to the discovery of neoteinics or substitute royalties which continue the reproductive activities of the community following the death of one, or both, of the original pair.

Under certain circumstances, colonies may also be founded by neoteinics. If a few immature forms are separated from the parental nest, some of the young will soon change into neoteinics and form an independent colony. Subsidiary colonies may also be formed by parties of individuals if the scene of their activity is far removed from the parental nest.

With one exception, the species of Ceylonese Calotermitidæ of economic importance which have been studied, rarely extend their attack below ground level, and in such cases, independent or subsidiary colonies by neoteinics are not usually formed. *Neotermes militaris*, however, attacks the roots as well as the upper portions of plants, particularly tea, and it also occurs in tree stumps in the soil. On a fully developed estate, tea

roots form a network in the soil and are often in contact with each other. When roots are contiguous, immature forms of termites readily migrate from one bush to another through the roots and form independent colonies. Members of Calotermitidæ (excepting *Paraneotermes simplicicornis*) do *not* travel from plant to plant through the soil.

The above method of infestation probably accounts for the large number of neoteinics of *Neotermes militaris* found in tea bushes. It is the usual mode of entrance to tea by this species. The abundance of food available to the insects which have migrated and the reduction of their numbers in the parental community in consequence of the formation of subsidiary colonies elsewhere, probably explain why winged forms of this species are not so commonly produced in the tea bush as they are in the case of other termite species which infest this host plant.

VI. POLYMORPHISM OR THE ORIGIN OF CASTES

It is not proposed to discuss at length in this paper the most interesting and important biological problem of caste production among termites, but brief reference may be made to the subject. The two theories which have been advanced to account for the origin of castes and the connected problem of the transmission of the characteristics of the sterile caste to the offspring are:

(1) that the castes are predetermined in the egg, *i.e.*, due to intrinsic causes; and

(2) that the castes are not due to hereditary factors but are determined at a later stage in the development of the undifferentiated, immature insects due to extrinsic factors, such as nutrition.

The nutritional hypothesis has been rejected by most modern biologists for want of supporting evidence and because they hold the view that a young termite, upon emergence from the egg, is already predestined to develop into a particular caste. Although the young larvæ at the time of hatching are externally alike, it is claimed by those who hold this view that they are internally differentiated. This view has been supported by the histological studies of Thompson (1917-1922) who deals with the relative dimensions of the brain, eye rudiments, and sexual organs of the various individuals believed to be the prototypes of the different castes. It also finds support in the observations of other workers.

In the opinion of the writer, based upon the observations described above, termite castes are not due to blastogenic or intrinsic causes but are determined later on in the ontogeny of the individual. The fact that neoteinics, both apterous and brachypterous, can be raised in the laboratory as required by isolating a few immature forms, selected at random, not only discredits the assumptions of Thompson and others but also proves

conclusively that these forms are not predetermined in the egg. Other observations by the writer also point to the same conclusion. Considerable confusion has been introduced into the problem by the histological studies referred to and by failure to give adequate consideration to the biological observations which have been made on these insects.

Further work, it is hoped, will yield more definite evidence, particularly in regard to the development of soldiers, to solve the problem of the origin of polymorphism among termites which, as Imms (1931) aptly remarks, has been "the perennial enigma that has exercised the minds of so many biologists".

VII. Acknowledgment

The above observations were made, or collected, while assisting Mr. F. P. Jepson, late Deputy Director of Agriculture, in his investigations on the various termite problems in Ceylon and the writer's thanks are due to him for his interest and encouragement in this investigation.

VIII. Summary

This paper summarises the numerous observations, results of laboratory experiments and other interesting data on the biology of Ceylonese termites of the family Calotermitidæ, several species of which are of considerable economic importance. The introduction includes a brief general account of termites and their status as pests. It also indicates the importance of the study of their interesting social organization, both from the scientific and economic point of view. A summary of the classification of termites (Isoptera) is given and the genera of Calotermitidæ represented in Ceylon are enumerated. This is followed by a brief account of the biology of the Isoptera, relative to the founding of colonies, nesting and feeding habits, development and intestinal protozoa, and followed, in turn, by a presentation of the general biological features of the Calotermitidæ.

A complete list of the Ceylonese Calotermitidæ known to the present time is recorded, together with brief notes on their habitat, economic importance, distribution and other information of interest concerning each species. The next section presents observations on the biology of the castes of the Calotermitidæ. The inherent difficulties in the study of termites are discussed and techniques devised for the successful breeding of damp-wood and dry-wood-nesting termites are described.

The different castes in communities of Calotermitidæ are mentioned. A summary of the observations on the development of eggs, larvæ and nymphs, and on instars is given. Stress has been laid on the aptitude of the immature individual to arrest larval or nymphal development in response to the needs and circumstances of the colony, a fact which indicates the variability of the life-cycle period. An account of the development and

occurrence of the various adult castes of the Calotermitidæ is given. In addition to observations on the macropterous and soldier castes, much information on the little known subject of the biology of neoteinics is included.

It has been pointed out that apterous or brachypterous neoteinics are developed from undifferentiated larvæ or nymphs in the absence of functioning deälated adults in a colony, or in parties of immature forms separated from the parental nest. In the laboratory they can be easily raised by isolating a few larvæ or nymphs, some of which, after a moult, attain the neoteinic condition. At this moult, a reduction in size of the wing-pads of nymphs sometimes occurs. Attention is also directed to an observation of a surprising phenomenon of a similar nature whereby, under certain circumstances, a nymph is able to inhibit the development of the wing-pads even when they have attained considerable size. At each moult, a reduction of the wing-pads is effected until their complete suppression has been achieved.

The statement that neoteinics cannot survive alone and are dependent on the immature forms for their existence has been disproved and the belief that neoteinics breed true to type, and hence cannot give rise to the macropterous form, has been dispelled as a result of extended breeding experiments. Among other facts which have not hitherto been recorded by previous workers is the appearance of the winged adults in a colony resulting from the mating of a winged male with a neoteinic female.

The establishment of colonies both by winged adults and neoteinics under certain circumstances has been referred to and particular attention has been drawn to the mode of founding colonies in tea bushes by the neoteinics of *Neotermes militaris*.

Finally, very brief reference is made to the most important and interesting biological problem of polymorphism or the origin of castes among termites. The results of observations recorded in the paper do not support the generally accepted modern view that castes are due to blastogenic or intrinsic causes but point to the conclusion that they are determined subsequently during the ontogeny of the individual.

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NOTES ON SOME SOUTH INDIAN MEALY-BUGS*

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INTRODUCTION

The great majority of insects commonly known as mealy-bugs are members of the Coccid subfamily Dactylopiinæ, but there are a few others also which belong to the subfamily Monophlebinæ, e.g., species of the genera *Icerya* Sign., *Drosichiella* Morris., etc. Except in the case of some well known forms with pronounced external peculiarities, it is very difficult to correctly identify the different species of mealy-bugs from superficial characters alone. For a correct specific identification, the female insect has to be prepared for microscopic examination in order to make out the minute specific differences. The specific structural differences are to be found chiefly in the anal armature, antennæ, legs and pores found in different regions of the body.

In South India ten genera of the Dactylopiinæ have been recorded so far: *Pseudococcus* Westw., *Trionymus* Berg., *Phenacoccus* Cockll., *Ripersia* Sign., *Antonina* Sign., *Pseudantonina* Green, *Rhizoecus* Kunkel, *Dactylopius* Costa, *Xenococcus* Silv., and *Kermicus* Newst; of these the first four are of economic importance. The subfamily Monophlebinæ is represented by *Aspidoproctus* Newst., *Labioproctus* Green, *Drosichiella* Morrison and *Icerya* Sign., the last two including important pests. Though many of the species dealt with here have already been figured and described by the writer[1] with notes on their morphology and ecology; an attempt is made in this paper to give a general and popular idea of the species of this group of insects so far noted from S. India to help, if possible, the amateur worker in and the educated cultivator in S. India.

Subfamily DACTYLOPIINÆ

Ferrisiana virgata (Cockerell)—The common tailed mealy-bug.

This is a common and widely distributed species, characterised externally by a pair of long, stout, waxy filaments at the tail end. In S. India it has been noted so far on garden crotons, tomato, pepper, cotton, *Lantana*, custard-apple, *sesbania grandiflora*, etc. Very often it assumes

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[1] AYYAR, T. V. RAMAKRISHNA, 1930, *Bull. Imp. Inst. agric. Res. Pusa*, No. 197.

pest status and covers shoots and fruits of custard-apple, tomato, lab-lab, etc. It has been noted in many other tropical countries also.

Pseudococcus lilacinus (Cockerell)

Colonies of this insect in mealy masses are generally found covering shoots of tamarind, *Sesbania*, *Ailanthus*, etc. It has also been noted as a pest of pomegranate, covering the fruits and fruit-stalks in woolly patches. It was also found in cracks and crevices in the stem of the banyan tree in the N. Circars, and on rubber in Ceylon. The Lycænid caterpillar, *Spaligis epius* Moore and the Noctuid caterpillar, *Eublemma scitula* (Ramb), are sometimes found as predators on this mealy-bug.

Pseudococcus filamentosus var. **corymbatus** Green—The cotton mealy-bug.

This is a common pest found on tender shoots and fruits of jak, *Citrus*, cotton, etc., in different areas. Cotton sometimes suffers very badly in some tracts during certain seasons. The notorious red ant (*Oecophylla smaragdina*) is an important agent in the distribution of this mealy-bug in many localities.

Pseudococcus saccharifolii Green—The yellow mealy-bug of sugarcane.

This insect is fairly common in N. India as a pest of sugarcane. It has, however, been noted in the Godavari District chiefly on wild cane, *Saccharum arundinaceum*. It clusters on the leaf sheaths and has a pale yellowish colour.

Pseudococcus bromeliæ Bouché—The pine-apple mealy-bug.

The species, though not very common in India, has been noted on pine-apple, especially on the fruits in N. Malabar on two or three occasions. It has also been recorded on mulberry in Bengal ; but the identification does not appear to be quite correct in the latter case.

Pseudococcus detorquens Green (MS.)

This is a species collected by the writer on bamboo shoots from the Walayar forests (Western Ghats). Young shoots of growing bamboo are found covered over by the insect in large numbers.

Pseudococcus distichlii var. **indicus** Green (MS.)

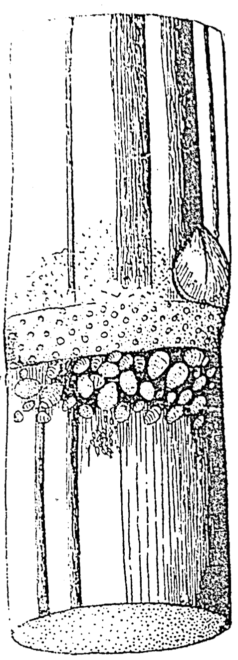
This is a new variety collected on the grass, *Leptochloa polystachya*, in the Tanjore delta.

Pseudococcus longispinus Targioni The coconut mealy-bug.

This mealy-bug is found infesting the unopened tender shoots of the coconut palm in different parts of the province; in badly infested trees the shoots are covered by colonies of the bug which cause them to fade and turn pale. Various species of ants visit them in enormous numbers. Young coconut trees often suffer from this pest. It has also been noted occasionally on the tender shoots of the palmyra palm, and on coffee and cedar-wood in Mysore.

Pseudococcus citri Risso The Citrus mealy-bug.

This is a well known insect enjoying a very wide distribution all over the tropics. It is known to be a very destructive *Citrus* pest in many fruit-growing areas of the world. The species is polyphagous, having been noted



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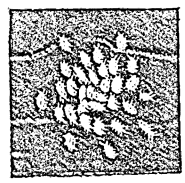

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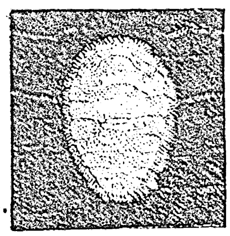

3.

FIGS. 1—3. *Trionymus sacchari* (Green)
1. a portion of sugarcane stem with the sheath removed to show the mealy-bug; 2. young larvæ; 3. later stage of larva.
(Reproduced from *Bull. Imp. Inst. Agric. Res. Pusa*, No. 197).

to attack more than forty different plants. In S. India it has been noted on cacao pods in the Nilgiris, coffee seedlings in Coorg, and on roots and

shoots of *Erythrina*, croton and *Parkinsonia* in different areas. Two other species of *Pseudococcus*, viz., *P. viridis* Newstead and *P. cocotis* Maskell, have also been noted in S. India, the former on *Pithecolobium saman* and *Hygrophila spinosa* in Madras in 1892 and the latter on coconut leaf in the Laccadive Islands in 1891. There are no further records of these and it is not unlikely that these may belong to one or other of the species noted above.

Trionymus sacchari (Cockerell)—The pink mealy-bug of sugarcane.

This is a very widely distributed species (Figs. 1—3) noted in many areas throughout the tropics. In India it has been noted in all cane-growing areas, such as S. India, Bombay, United Provinces, Bihar, Bengal, etc. This insect generally confines itself to sugarcane and a few grasses only. It is often found as a serious pest of sugarcane during certain seasons and on certain varieties of cane. The adult female has a uniform light pink colour and is elongate oval in shape; the mealy covering is loose. It was for many years confused with the rice mealy-bug causing the *soorai* disease but the latter has recently been described as a separate species (*Ripersia oryzæ*) by Green. Green has recently noted a new variety of *Trionymus* (*T. distichlii* var. *indicus*) from Tanjore; but it has not yet been described.

Phenacoccus insolitus Green—The brinjal mealy-bug.

This species is commonly noted on old brinjal plants. A badly infested plant is covered over with colonies of these insects in all stages, and from a distance it looks as though the plant has been splashed with whitewash. It has also been found on *Sida*, *Tribulus*, *Triumfetta*, *Abutilon*, and *Acheranthes aspera* at Coimbatore and Malabar. A predatory lady-bird beetle and a small parasitic wasp have been noted as natural enemies of this mealy-bug.

Phenacoccus mangiferæ Green—The mango mealy-bug.

A common pest in all mango-growing areas, especially in Salem, N. Circars, Chittoor, etc. The adult female is broadly oval with numerous long, stout, marginal processes on all sides. It has also been found on *Eugenia hemispherica* and *Echitis* sp. in Tinnevelly and the N. Circars.

Phenacoccus iceryoides Green

This insect has been noted to attack a number of plants. The chief among them are *Citrus*, *Boswellia*, *Plectronia*, *Capparis*, *Ficus*, *Dolichos*, cotton and the rain tree. Sometimes it is found as a serious pest on the rain tree. The caterpillar of the butterfly, *Spalgis epius*, feeds on this mealy-bug.

Phenacoccus ornatus Green—The jasmine mealy-bug.

This is a creamy-white, delicate insect with the body roundish and with the white waxy processes arranged as fine radiating filaments; noted on wild and cultivated jasmines. It is recorded also on tea leaves in Ceylon.

Phenacoccus hirsutus Green—The tukra mealy-bug.

This species has a wide distribution all over N. India. It is known to cause the peculiar malady known as 'tukra' disease on mulberry, grown to feed silkworms in Bengal. It is known as the 'Hibiscus mealy-bug' in Egypt. The insect was recorded from S. India by the writer on the banyan tree in North Coimbatore, and on the tender distal shoots of teak trees in the Walayar forests.. It has not been noted so far on mulberry in the silk-rearing areas of the Mysore plateau.

Phenacoccus quarternus Green

There is only one record of this insect having been found in cracks of *Casuarina* tree in the Coromandal coast in 1912.

Ripersia sacchari Green

This species was first recorded from the United Provinces on sugarcane. It is not so common as the pink mealy-bug (*Trionymus sacchari* (Cockerell). In S. India till now it has only been found on *Imperata* grass in Tanjore and on wild cane, *Saccharum arundinaceum* in the Northern Circars.

Ripersia oryzæ Green

The disease known as *soorai* on paddy often found in the different rice-growing areas of the province, especially in the Tanjore delta, is caused by this mealy-bug. In infested fields the insect can be found in large numbers on the paddy plant under the leaf sheaths and on the stem; the sucking up of the plant juice by hundreds of these creatures causes the plant to shrivel and be stunted and in many cases no earheads develop. For some years past this insect was confused with the pink mealy-bug of cane and passed under the name *Trionymus* (*Pseudococcus*) *sacchari*. Recently Green found out the error and described this insect under the name *R. oryzæ*. A general account of this insect and its relations with the rice plant as a pest is given in the writer's recent paper[1] on the subject. Two new species of *Ripersia* (*R. rigida*, & *R. punctatissima*) also have been discovered by Green in the material collected on grasses (*Iseilema* and *Cyperus*) from both the Tanjore and Godavari districts; but these have not yet been described.

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[1] Ayyar, T. V. Ramakrishna, *J. Mysore agric Expt. Union*, **17**: 1-10, 1939.

Antonina maritima Green—The nut-grass mealy-bug.

The habitat of this insect is generally the underground roots of grasses of different kinds. This has been found on *Cynodon* grass in Coimbatore.

Antonina indica Green

Similar to the last species and found attached to grass stem close to the soil. This has also been recorded from Bengal and Ceylon on grass. The insect is found in pale, white, ovoid patches in the lower regions of grass stems at Coimbatore.

Antonina zonata Green

Found on bamboo shoots and stems in Coimbatore. The species was first described in 1919 from material collected on bamboo in Ceylon.

Pseudantonina Green

Two new species of the genus *Pseudantonina* have been recently discovered by Green from material collected on grasses from the Godavari district, but have not yet been described.

Rhizoecus cynodontis Green

This is also a grass-infesting species, collected on *Cynodon dactylon* in the Godavari district by Y. R. Rao. It was described by Green in 1931.

Dactylopius tomentosus Lamarck—The prickly-pear mealy-bug.

This is the insect (Fig. 4) which has done a considerable amount of good work during the past few years in killing our worst weed, the prickly-pear in extensive areas all over S. India. It confines itself to one food plant *viz.*, the prickly pear, *Opuntia dillenii* Haw. In general form, the female insect is oval and completely covered over by dense, mealy-white covering. This cochineal was first introduced into India *via* Ceylon by about 1926 and since then it has spread throughout S. India and has helped a great deal in clearing many extensive areas of this weed. A detailed account of this and the allied species, *D. indica* Green may be found in the author's paper on the Coccidæ of prickly-pear in S. India 1931.[1] The allied species *D. indica* Green is now very scarce and confines itself chiefly to another species of prickly-pear *viz.*, *O. monacantha*.

Xenococcus annandalei Silvestri

This insect was noted only once on roots of *Ficus obtusa* in the nest of an ant of the genus *Acropyga* in the N. Circars.

[1] AYYAR, T. V. RAMAKRISHNA, *Agric. Live-stock, India*, **1** (3): 229-237, 1931.

Kermicus wroughtoni Newstead—The bamboo mealy-bug.

Colonies of this interesting insect were found inside hollow bamboos in Malabar with swarms of ants visiting them. The insect was first described by Newstead from material collected from India as early as 1897.

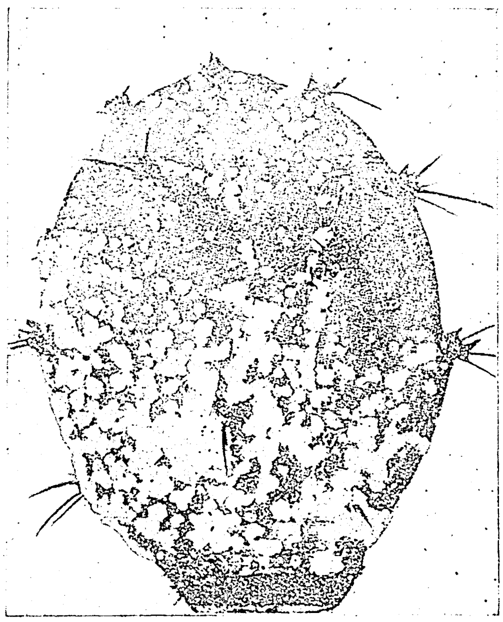

Fig. 4. Stem of *Opuntia dillenii*, attacked by *Dactylopius tomentosus*.

(Reproduced from *Bull. Imp. Inst. Agric. Res. Pusa*, No. 197)

Subfamily MONOPHLEBINÆ

In this subfamily, as stated before, we have only two genera which are also known as mealy-bugs; these are *Icerya* and *Drosichiella*. Sometimes species of these two genera become serious pests. The native species of *Icerya* so far noted in S. India are: *I. ægyptiaca* Douglas, *I. seychellarum* Westwood and *I. pilosa* Green. In general external form they are all more or less similar, with the mealy covering of the body forming numerous conspicuous elongated, stout, waxy filaments. The commonest of the three is *I. ægyptiaca* which attacks numerous plants, such as garden crotons and ornamental shrubs of all kinds, jak, *Ficus*, mango and numerous other cultivated plants. *I. seychellarum* is not so common and has been noted on *Cassia* and *Casuarina*. It has been recorded on mango in Bombay. *I. pilosa* is a rare species and has been noted on *Spinifex squarrosus* near Madras. One other species of *Icerya, viz., I. purchasi* Maskell, an Australian form has within the past few years, entered India and is found on wattles and *Citrus* in the Nilgiri hills. It is a notorious pest of *Citrus* and other fruit trees in many countries. The progress of this insect in India has to be watched. Only one species of *Drosichiella* has so far been found fairly common in S. India. This is *D. phyllanthi* (Green), noted on garden crotons, *Cleistanthus*, etc. The females of this insect are some of the biggest among mealy-bugs; they are flattish-oval in shape, pale dirty white in color, with dark limbs. In N. India one species, *Drosicha mangiferæ* (Green),* has been found as a serious pest of mango and other fruit trees.

It is hardly necessary to add that there is a good deal yet to be studied regarding mealy-bugs in S. India; nor is it unlikely that many new forms await discovery.

*Some authors have recorded this species under the name, *Monophlebus stebbingi* (*Ed.*).

NOTES ON THREE PREDATORY HEMIPTERONS FROM SOUTH INDIA

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INTRODUCTION

The leguminous plant *daincha* (*Sesbania bispinosa*) is an important 'green-manure' plant grown in many districts of the Madras Presidency, especially in the wet areas of the Cauvery delta. It has been found subject to the attacks of a number of caterpillar pests, of which *Prodenia litura* (Fabr.) and *Semiothisa pervolgata* (Wlk.) are the important. In addition to these, the larvæ of the butterflies, *Terias hecabe* (Linn.) and *Catopsilia pyranthe* (Linn.) are also occasionally noted in small numbers. During the course of studies of these pests at the Agricultural Research Station, Aduturai, South India, three predatory bugs were observed feeding on these caterpillars. The present paper deals with the habits and life-histories of these predators and their efficacy in controlling the pests.

PENTATOMIDAE

Cantheconidia furcellata (Wolff)

It has some resemblance to the bugs *Dolycoris indicus* Stål. and *Agonoscelis nubila* (Fabr.), which are often found in association with it. It can be distinguished from the others by its lateral spines found on the thorax. Its habits have been described by Lefroy (1909) and Fletcher (1914).

Distribution.—In the Madras Presidency *Cantheconidia furcellata* has been recorded from Coimbatore, Saidapet, Aduturai and Musiri. Outside the province, it has been noted in Bihar and Bengal. According to Distant (1902) this is a widely distributed species, recorded from both the Oriental and Nearctic regions.

Life-history.—The males are slightly smaller than the females. They mate at any time of the day and remain *in cop* for several hours. Eggs are laid in numbers varying between 8 and 60 at a stretch, usually in two rows, either a few inches below the tip on the growing shoot or on the leaves of the food-plant. Under laboratory conditions, eggs are laid during night or day on the *daincha* twigs supplied in the breeding jars, sometimes on the sides of the glass jar or on the muslin covering provided for the jars. The maximum number of eggs laid by a single female is 180 and the minimum 25.

The egg is shaped like a flower-pot, the top being slightly wider than the bottom. At the top there is a lid fitted with a raised rim, which is provided with 18-20 small projections. The freshly laid eggs are whitish and glued on to the host plant by means of an exudation from the mother insect and are therefore not easily dislodged. Different regions can be seen in the lid too, the centre of which is dull white, surrounded by a ring of light blue colour. Just before hatching, the egg changes its colour to light orange. The incubation period ranges from 5 to 7 days.

The nymphs hatch by pushing their way out at the top. The newly hatched nymphs are light orange-yellow in colour and measure 1 mm. in length. The nymphs undergo five moults before they attain the adult form. The duration of the life-cycle from the egg to the emergence of the adult is 18 to 21 days. Under laboratory conditions, the adults were found to live for 15 to 20 days.

Feeding habits.—Both the adults and nymphs introduce their proboscis into the host caterpillars, which struggle hard to extricate themselves. But once the piercing is effected, the host can only rarely escape being sucked out. It was noticed that when fresh green twigs and caterpillars were offered in breeding jars at the same time, the bugs fed on the plant sap first and only later turned their attention to the insect-food. They do not possess the typical predatory trophi of the Reduvidæ.

Hosts.—Under field conditions, the bug has been noted to feed on caterpillars of *Semiothisa pervolgata* (Wlk.), *Terias hecabe* (Linn.), and *Catopsilia pyranthe* (Linn.), feeding on *daincha.* Under laboratory conditions, the bug was found attacking the following caterpillars:—*Tarache nitidula* (Fab.), *Earias fabia* (Stoll.), *Orthaga* sp., *Spodoptera mauritia* (Boisd.), *Cirphis unipuncta* (Haw.), *Psalis securis* (Hübn.), *Euproctis fraterna* (Moore), *Argina cribraria* (Clerck), *Hypsa sericea* (Moore), *Utetheisa pulchella* (Linn.), *Amsacta albistriga* (Wlk.), *Eupterote mollifera* (Wlk.), *Stomopteryx nerteria* (Meyr.), *Sylepta derogata* (Fabr.), *Schœnobius incertellus* (Wlk.), *Scirpophaga* sp., *Papilio demoleus* Linn., *P. aristolochiæ* (Fab.), *Acherontia styx* Westw., *Melanitis ismene* Cram. and *Parnara mathias* (Fabr.).

Natural enemies.—A Scelionid egg-parasite of the bug has been reared from the field material ; this is probably *Microphanurus seychellensis* (Kieff.) (Serphoidea).

Andrallus spinidens (Fabr.)

A description of this species was given by Distant (1902). *Andrallus spinidens* (Fabr.) can be differentiated from *Cantheconidia furcellata* (Wolff), by the pale brownish colour and the presence of two long, widely separated white streaks, one on each side of the tegmen in the former.

Distribution.—According to Distant, this is a widely distributed species, recorded from several islands of the Malay Archipelago, Fiji, Tahiti, East Africa and Mexico. In India, the following localities are given by the same author : Sikkim, Assam, Harnath, Khasi Hills, Bengal, Karachi and Bangalore. In the Madras Presidency, this species has been recorded from Godavari, Kurnool, Saidapet, Coimbatore and Aduturai.

Seasonal incidence.—The bug makes its appearance about the middle of April. The *daincha* crop is sown in December-January. The caterpillar pests appear about a month thereafter. The predator is, however, seen in stray numbers in the field only two months later. By this time, the pest has almost passed through one generation. With the advance of summer, however, it begins to multiply rapidly. It appears to thrive best at a maximum temperature between 94°F and 104°F and a minimum between 70°F. and 80°F., under a low relative humidity. Though these bugs appear in the hot weather, it is in the period of south-west monsoon that they are active, after which they dwindle in numbers. The north-east monsoon adversely affects the insects in the field.

Life-history.—The eggs are generally laid two or three days after emergence in numbers varying between 28 and 160 at one time, mostly in two rows. The maximum number of eggs laid by a female was 256, while the minimum was 28. The egg is broader at the top than at the bottom and closed by a lid fitted into a raised rim, ornamented by 18-20 projections. The freshly laid egg is flesh-coloured and fastened on to the host plant by a sticky fluid. Before hatching, the colour of the egg changes into light orange. The inculation period is on the average 6 days. During the rainy weather it may be 8 or 9 days.

Nymphs.—The freshly hatched nymphs are light orange-yellow in colour and measure 1 mm. long. Within one or two hours the nymph becomes piceous. There are five instars ; the first four instars last 2 to 3 days, while the last occupies 3 to 4 days.

The life-cycle from the egg to adult varies from 18 to 21 days. Under laboratory conditions the adults were found to live for 15 to 20 days after emergence.

Feeding habits.—The adults and nymphs follow the prey and attack it from behind or from the flank. Once the enemy is sufficiently near, the proboscis is introduced in an outstretched position. In the case of very big caterpillars, the piercing of the proboscis is not easily effected as the former turns and attacks the enemy. When one bug is not able to subdue the prey, the struggle is noted by the others nearby and they also attack the caterpillar, some from behind, others from front and a few others from the sides. Very young caterpillars are quickly sucked

out. Each adult or nymph devours per day 2 or 3 full-grown caterpillars of *Prodenia litura* in captivity.

Hosts.—Both the adults and nymphs attack a variety of insects. In the *daincha* fields at Aduturai, the bug was found feeding on *Prodenia litura* (Fabr.), *Semiothisa pervolgata* (Wlk.), *Catopsilia pyranthe* (Linn.) and *Terias hecabe* (Linn.). Under laboratory conditions, the caterpillars mentioned in the case of *Cantheconidia* were also attacked and fed upon. Besides these, it feeds also on some dipterous maggots and grubs of some Coleoptera. Fletcher (1914) reported that the bug was found feeding on *Chloridea obsoleta* (Fab.) at Coimbatore. According to Lefroy, it has been noted preying upon the larvæ of *Thermesia rubricans* (Boisd.). Cannibalistic tendencies are noted in this bug as well as in *Cantheconidia furcellata* (Wolff). When the nymphs are moulting, other nymphs and adults close by take advantage of their helpless condition and suck out their contents.

REDUVIIDAE

Rhinocoris fuscipes (Fabr.)

Rhinocoris fuscipes was observed throughout the districts of Tanjore and Trichinopoly, but only in very small numbers.

Life-history.—Eggs are laid in batches varying from 5 to 21 and arranged vertically. The egg is elongated, more or less cylindrical and of olive colour. The incubation period is 6 or 7 days. The newly hatched nymphs look like small ants. At this stage the abdomen is attenuated, while the head and thorax are normal. There are five moults before the adult form is reached. The nymphal period ranges from 30 to 50 days. The maximum duration of life was about three months. The maximum number of eggs laid by a female was 80 and the minimum 45.

Hosts.—In addition to the *daincha* caterpillars, the bug was found feeding on the beetles *Epilachna 12-stigma* Muls. and *E. 28-punctata* and the pumpkin-beetle, *Aulacophora foveicollis* Lucas in the field. Under laboratory conditions, the bug was found feeding on the caterpillars mentioned as hosts of the two Pentatomid bugs above. Two or three caterpillars form the maximum feed per day.

Parasites and diseases.—No parasite was found but the bugs were found subject to a bacterial disease, particularly during the rainy season, as was the case with the other two bugs. When affected by the disease, the bugs refrain from feeding and remain still without any kind of movement. The body of the bug rapidly turns black and a bad odour emanates from it.

EFFICACY OF THE PREDATORS AS CONTROLLING AGENTS

The predatory bugs mentioned above have some drawbacks which prevent them from being effective. They require an equal, if not longer,

period to complete their life-cycle as compared with the hosts. Their egg-laying period is spread over a period of 8 to 10 days, before which the moths lay their full complement of eggs and the caterpillars resulting therefrom often assume pest proportions. Under laboratory conditions, a predatory bug kills only 2 to 3 caterpillars per day, which number does not seem to be effective in controlling the pest. The bugs themselves have their natural enemies. The predator *Cantheconidia,* has a Serphoid egg-parasite. Again, the adult bugs of all the three species are found subject to a bacterial disease, particularly in certain seasons of the year. It is also seen that fresh hatchlings of two of the predators, *Cantheconidia* and *Andrallus,* feed on the plant sap for the first few days and only later on take to juices of insects. Finally, though the bugs under laboratory conditions feed on a variety of caterpillars, large scale breeding of bugs is beset with difficulties during the monsoon rains. During the wet season, a disease appears in breeding jars and affects the nymphs, which die in large numbers.

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EFFECT OF COLOURED SCREENS ON OVIPOSITION AND DEVELOPMENT OF SOME BRITISH WHITE-FLIES*

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CONTENTS

I. INTRODUCTION

The relation between the living organism and its environment is not fully understood. Experimental evidence is put forward in favour of the relationship between insects and the micro-climatic factors, such as temperature and humidity, but the study of the effect of light has so far been very much neglected. Some interest was shown in this problem towards the close of the last century, but soon it drifted to other fields. The effect of light on animal disease, migration and even reproduction received some attention during the last decade, but the influence of the individual components of spectrum, has not been thoroughly studied, apart from that of violet rays. Since phototropism has been successfully exploited as an effective control measure against some of the injurious species, it may be presumed that the reproductive activities of the adults, as well as their immature forms, may be equally sensitive to the passive influence of light in general and its various components in particular.

White-flies, (Aleyrodidæ) generally live on the under side of leaves, and the infestation is relatively severer in shady places. It is, therefore, quite likely that the various shades of light may have some significant effect on their multiplication.

*The work was carried out at the Rothamsted Experimental Station, Harpenden, England, during 1936-38.

II. REVIEW OF PREVIOUS LITERATURE

Beclard (1858) stated that the larvæ of *Musca carnaria* Linn. attained the largest size under violet light and next in order under blue, red, yellow and white. Zhmuidzinovitch (1891) remarked that the quickest development of silkworms was under blue light and it decreased in the order of yellow, white, violet, red and green. Gal (1899) differed from the previous views and stated that violet light favours the growth of silkworms, the weight of cocoon, silk and egg-laying. Flammarion (1899) asserted that the ordinary diffused light produces relatively greater amount of silk per cocoon than any coloured light. Linden (1899) explained that the largest adults of *Vanessa urticæ* Linn. were obtained under blue light and those of *Vanessa io* Linn. in darkness, owing to the absence of heat rays.

Lloyd (1922) stated that both the sexes of *Trialeurodes vaporariorum* (Westwood) are attracted to yellow traps. Marcovitch (1924) suggested that development of sexes and migration to alternative hosts of several species of Aphididæ are governed by length of day time. Northrop (1925) found that the larval period of *Drosophila* is shortened at intensities of about 2,500 meter-candles. Barber (1925) noticed that the European corn-borer moth, *Pyrausta nubilalis* (Hübn.), produces larger number of eggs when kept under constant darkness. Shelford (1927) remarked that the pupal stage of the codling moth is prolonged in darkness. Janisch and Maercks (1933), experimenting on *Pieris brassicæ* Linn., concluded that they prosper and develop to the adult stage as well in darkness as in light and the developmental period is not affected by the absence of light. Kogure (1933) studying the effect of light on silkworm moths concluded that red light affects the insect as much as the dark, orange-yellow gives results almost similar to the red, and that violet light produces a larger number of silkworm moths, laying dark coloured eggs as in the white light. Ilse (1937) concluded that the cabbage white-butterfly favours green and bluish-green lights for egg-laying. Snow (1937) pointed out that it was possible to control or change the sexual periodicity by introducing the factor of coloured lights. Evidently the conclusions of different workers are, on the whole, very conflicting in this respect.

III. TECHNIQUE

During these investigations flower pots of 8″ or 6″ sizes, containing respectively $7\frac{1}{2}$ lbs. and 5 lbs. of soil, were used. The cultural operations were similar for all the plants under observation. Each pot had a single seedling and the leaf of almost same position was selected for all replications when covered with coloured cages.

The cages (Fig. 1) were made of cellophane of practically uniform thickness. Each cage was a tube about 4″ long and $2\frac{1}{2}$″ in diameter, open

at one end but supported at both ends by rings of card-board. The closed end was perforated with about 150 pin-punctures for ventilation. The cage in position rested on a small glass tripod at the base and a Y-shaped support of cane on one side. The lower open end was plugged with cotton wool. Each experiment had 2-4 replications.

For comparative oviposition equal number of newly emerged females was introduced in various cages, and were allowed to stand for about half an hour before the cages were put over the selected leaves. The eggs laid on the leaves were counted at regular intervals.

For observation on the incubation period, eggs were obtained on the selected leaves under a lamp glass. The adults were removed after 24 hours and the leaves were covered over again by the cellophane cages. Hatchings were observed daily and the nymphs that hatched were counted and killed.

FIG. 1. A breeding cage.

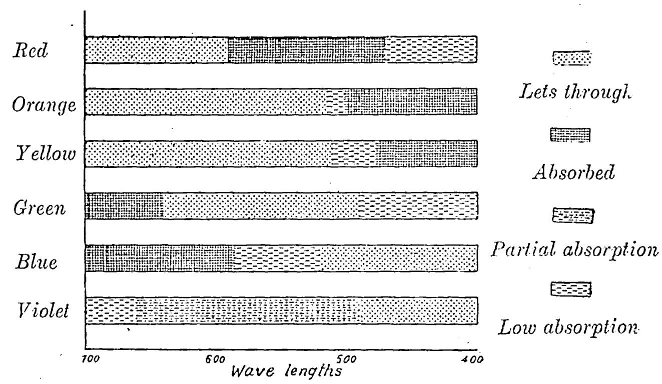

FIG. 2. Absorption of the wave lengths through cellophane screens.

For the duration of nymphal stage, eggs were obtained as above and were allowed to hatch under the same lamp glasses. The nymphs, which hatched in small numbers, were removed every day, till sufficient number hatched on all the leaves on one and the same day. The leaves with the newly hatched nymphs were then enclosed in the respective cages after the remaining eggs were destroyed. The emergence of adults was then recorded.

For each experiment replications were spread out on one table and thus they were exposed to practically the same temperature. This was tested by actual observations and very little differences were observed in the temperature of various cages.

The range of wave lengths in millimicrons of the solar rays let through or cut off by the coloured cellophanes (Fig. 2) was studied by spectroscope. The relative intensities of light rays transmitted through these cellophanes were measured by Weston's photo-electric cell and

TABLE I. *Relative intensities of light rays transmitted through cellophane, as measured with the Weston's photo-electric cell.**

Screens	Relative intensity of light transmitted												Average intensity	Percentage intensity
							(B)	(A)						
Ordinary light	500	650	340	360	320	90	800	225	250	225	160	180	341.7	100.0
Colourless	450	600	320	350	285	80	750	200	225	200	145	170	314.6	92.1
Violet	320	340	200	225	145	20	425	160	130	145	115	115	195.0	57.1
Red	250	267	140	180	115	15	400	145	120	120	100	100	162.7	47.6
Green	360	400	265	250	180	40	500	170	180	160	120	140	230.4	67.4
Yellow	390	450	320	320	200	52	575	200	180	180	130	150	262.3	76.7
Orange	380	400	285	250	180	40	500	170	180	165	125	140	236.6	69.2
Blue	265	320	225	200	115	15	400	145	130	145	100	100	180.0	52.6

*Relative intensities of light transmitted are recorded by deflections of the needle of the photo-electric cell; each division of the scale representing a light intensity of 0.71 foot-candle.

(A) Observations on the right of the mark were taken without pressing the button. (B) Observations in this series were taken in the sun.

the results are shown in Table I. The data kindly supplied by the British Cellophane Company, London, in this respect, showed almost similar results, though with slightly different screens.

Two different species of Aleurodidæ namely, (1) *Aleurodes proletella* Linn., the cabbage white-fly and (2) *Trialeurodes vaporariorum* (Westwood), the glass house white-fly, were under observation during these investigations.

TABLE II. *Relative oviposition by* A. proletella *Linn. under different coloured screens*, 1936-39.

Colour of screen.	Number of times the experiment was repeated.	Average no. of eggs laid per female.	Remarks.
Red	5	1.12	1. Each experiment had 2-3 replications.
Orange	,,	1.57	
Green	,,	0.77	2. The number of females and the duration of oviposition varied in different experiments but they were constant in the replications of each.
Blue	,,	0.79	
Violet	,,	2.31	
Yellow	,,	3.92	
Colourless	,,	2.63	

Standard error ± 0.345 Significant difference 1.035

TABLE III. *Relative oviposition by* T. vaporariorum (*Westwood*), *under different coloured screens*, 1937-38.

Colour of screen.	Number of times the experiment was repeated.	Average no. of eggs laid per female.	Remarks.
Red	4	3.21	1. Each experiment had 3-4 replications.
Orange	,,	4.24	
Green	,,	3.27	2. The number of females and the duration of oviposition varied in different experiments but they were constant in the replications of each.
Blue	,,	2.33	
Violet	,,	4.80	
Yellow	,,	6.64	
Colourless	,,	5.83	

Standard error ± 0.335 Significant difference 1.005

IV. RELATIVE EFFECT OF COLOURED SCREENS ON OVIPOSITION.

(1) *A. proletella* Linn.—The maximum number of eggs, on an average, was laid under the yellow screens (Table II, and Fig. 3). The oviposition under the colourless and violet screens was also higher than under the rest of the coloured cages. However, the relative effect of different radiations, may be roughly arranged in three groups—(1) yellow (Y), colourless (W) and violet (V) showing the maximum number of eggs laid, (2) orange (O) and red (R), taking the middle position and (3) blue (B) and green (G), taking the other extreme, indicating the least number of eggs laid under their influence.

On statistical analysis the above results give a standard error of ± 0.345. Comparing the individual differences on the basis of the significant figure of 1.035, the following conclusions have been arrived at :—

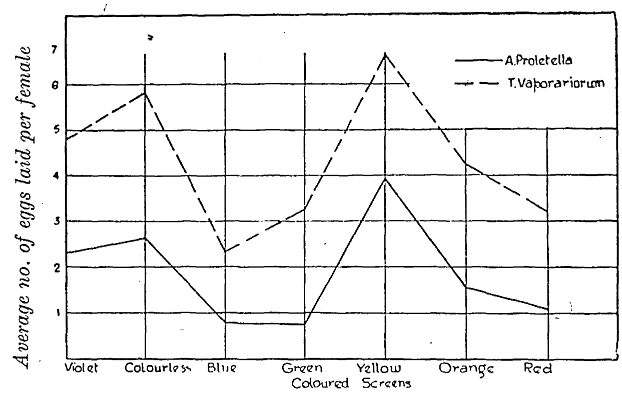

FIG. 3. Relative oviposition of *A proletella* and *T. vaporariorum* under coloured screens, 1936-38.

i. The average number of eggs laid per female is significantly higher under the yellow screen than under any other. At the same time, the colourless screen* shows significant differences from the means under red, orange, blue and green. The violet is also significantly different with the exception of the results under orange.

ii. The average difference between YWV group and the ROBG group is quite significant.

iii. The results of the red, orange, blue and green screens are not significantly different from one another.

(2) *T. vaporariorum* (Westwood).—The observations were made under conditions, practically identical to those for *A. proletella*, and the results are given in Table III and Fig. 3. The insects on the whole behaved practically in the same way as those of the previous species. The maximum number of eggs was laid under the yellow screen. The relative effects of the colourless and violet screens come next to the yellow ; and the grouping with respect to the relative oviposition under various screens, almost corresponds with that observed in *A. proletella*. The effect of the

*For convenience in grouping, it will be represented by "W", indicating white.

orange screen in this case lies somewhere between the YWV group and the GRB group. A slight difference was also noticed in the position of the red and green in this case, but their results in no way differ from those observed previously.

Statistical analysis of the data gave a standard error of ± 0.335, with a significant difference of 1.005. The following conclusions, therefore, are derived :—

i. The effect of the yellow screen is significantly different from that of all others, except the colourless (W) and gave the maximum number of eggs.

ii. The difference between the colourless and violet is also significant.

iii. The effect of violet is significantly different from that of green, red or blue, but not from orange, its effect in this respect exactly corresponds with that noticed in *A. proletella.*

iv. The differences between the green, red and blue are not significant as noticed previously, but the orange is significantly different from the red and blue.

The general trend of the results obtained in the case of both the species is almost similar with only slight differences with respect to the influence of violet and orange screens. The yellow and colourless screens invariably gave maximum number of eggs, whereas the red, green and blue gave the minimum number.

V. Relative effect of coloured screens on immature stages

a. *Duration of the egg stage.*

(1) *A. proletella.*—The response of the egg stage was determined from the percentage of eggs hatching under the various screens. (Table IV, Fig. 4) and from the average duration of the incubation period under respective cases (Table V). For the sake of convenience in representation, however, a standard effect was obtained by the accumulated totals and percentage of total hatching (Table IV).

Fig. 4 indicates : (i) that the eggs under red screen started with a relatively higher percentage of hatching ; (ii) the peak of the maximum hatching of eggs on any one day, was almost invariably one day earlier under the red screen.

Similarly when examined critically, the data in Table IV represent that over 60% of the eggs under red screen, hatched by the third day from the commencement of hatching : on the other hand, this limit was reached by the fourth day under other screens.

TABLE IV.—*Average daily hatching, accumulative totals and percentage of total hatchings of the eggs of* A. proletella *under different coloured screens*, 1937-1938.

Colour of Screen	Hatching	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	Remarks
		Days from the commencement of hatching of eggs.									
Violet	(A)	0.0	3.3	14.0	20.5	8.3	3.3	1.5	2.0	1.5	Hatching of eggs seems to extend over a relatively longer period under violet and colourless screens.
	(B)	0.0	3.3	17.3	37.8	46.1	49.4	50.9	52.9	54.4	
	(C)	0.0	6.1	31.8	69.5	84.7	90.8	93.6	97.2	100.0	
Red	(A)	7.0	20.0	33.0	23.3	2.0	0	0	0	0	
	(B)	7.0	27.0	60.0	83.3	85.3	0	0	0	0	
	(C)	8.2	31.5	70.3	97.7	100.0	0	0	0	0	
Colourless	(A)	0.3	4.0	12.3	19.3	14.8	4.5	0.8	0.5	0	Shortest duration of egg-stage, on an average, has been noticed under red screen.
	(B)	0.3	4.3	16.6	35.9	50.7	55.2	56.0	56.5	0	
	(C)	0.5	7.6	29.4	63.5	89.7	97.7	99.1	100.0	0	
Green	(A)	0.8	10.8	15.3	27.0	6.7	0.5	0.8	0	0	
	(B)	0.8	11.6	26.9	53.9	60.6	61.1	61.9	0	0	
	(C)	1.3	18.7	43.5	87.1	97.9	98.7	100.0	0	0	
Yellow	(A)	0.0	2.5	7.0	13.3	4.5	2.8	0.8	0	0	The percentage of earliest hatching under red screen was, on an average, higher than under any other.
	(B)	0.0	2.5	9.5	22.8	27.3	30.1	30.9	0	0	
	(C)	0.0	8.1	30.7	73.8	88.3	97.4	100.0	0	0	
Orange	(A)	0.3	6.5	16.0	15.5	4.2	2.0	0.3	0	0	
	(B)	0.3	6.8	22.8	38.3	42.5	44.5	44.8	0	0	
	(C)	0.6	15.2	50.9	85.5	94.9	99.4	100.0	0	0	
Blue	(A)	0.0	8.0	15.0	15.3	4.5	2.0	0.8	0	0	
	(B)	0.0	8.0	23.0	38.3	42.8	44.8	45.6	0	0	
	(C)	0.0	17.5	50.4	84.0	93.9	98.2	100.0	0	0	

A. Average hatching. B. Total hatching. C. Percentage of total hatching.

The general effect of the various screens, revealed by studying this data comparatively, leads to the following conclusions :—

i. The effect of the red screen is rather prominent, since the incubation period is minimum under its influence.

ii. Next in order, is the group constituted by orange, green and blue screens.

iii. The effect of yellow, colourless and violet screens represents the longest duration of the egg stage and the incubation period is particularly extended over a relatively longer period under violet and colourless screens.

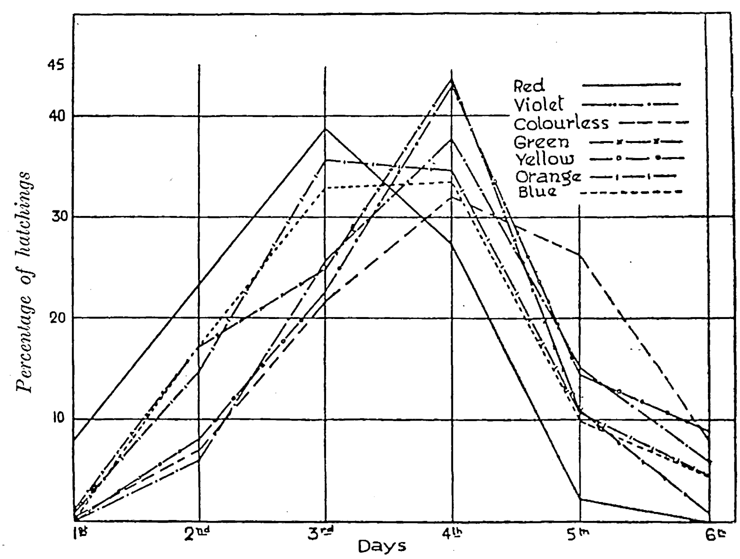

FIG. 4. Percentage of average daily hatch of *A. proletella* eggs under coloured screens, 1936-38.

Statistical analysis of the data from these experiments, gives ±0.178 as the standard error (Table V). Comparing the mean durations under various screens on the basis of the significant difference, the following conclusions are arrived at :—

i. The results of the red screen are significantly different from those of the rest.

ii. The influence of the violet, colourless and yellow screens is not significantly different from one another, as also noticed in the case of the orange, green and blue screens.

iii. The violet and colourless are both significantly different from all others except the yellow.

iv. The results under yellow are not significantly different from those under orange, green and blue. Hence the yellow falls roughly between these two groups.

(2) *T. vaporariorum*.—The results obtained with respect to the duration of the egg stage of this species are summarised in the same manner as in the case of *A. proletella* and are graphically represented in Fig. 5. The conclusions derived from this data are also almost identical with those given under the previous example, namely, (i) relatively higher percentage of hatching on the first day is noticed under the red screen; (ii) on an average,

TABLE V. *Hatching of the eggs of* A. proletella *under different coloured screens*, 1937-1938.

Colour of screen.	Average duration of egg stage (in days)				Mean.
	Number of experiments each with 3-4 replications				
	I	II	III	IV	
Red	12.80	11.89	11.10	11.44	11.81
Orange	14.33	12.75	11.42	12.15	12.66
Green	14.12	12.36	11.56	12.50	12.64
Blue	13.60	12.61	11.46	12.69	12.59
Violet	15.67	13.49	12.01	12.79	13.49
Yellow	14.77	12.91	12.00	12.79	13.12
Colourless	14.79	12.88	12.13	13.58	13.34

Standard error $\pm$ 0.178 Significant difference 0.534

the peak of the maximum hatching of eggs, on any day, is about 24 hours earlier under the red, although a similar tendency is also observed under the green and blue screens; (iii) over 60% of the eggs under red screen hatches by the 3rd day after the commencement of hatching.

The general effect of the various coloured screens (Fig. 5) shows practically the same distinct grouping as observed before. The maximum effect of the red screen is noticeable from the quickest development of the egg stage. Next in order are the results under the orange, green and blue screens; followed by the 3rd group representing the effect of the violet, colourless and the yellow screens which produce the slowest development of the egg stage.

Statistical analysis of these results gives a standard error of ± 0.116. Comparing the mean durations under various screens, on the basis of the significant difference, the following conclusions may be derived :—

i. The results of the red screen are significantly different from those of others.

ii. The differences between the results under violet, colourless and yellow screens are not significant ; similarly, the effects of the orange, green and blue screens do not indicate significant differences.

iii. The results of the violet and colourless screens are significantly different from all others except the yellow. Thus, the yellow screen behaves exactly similar to that under the previous example.

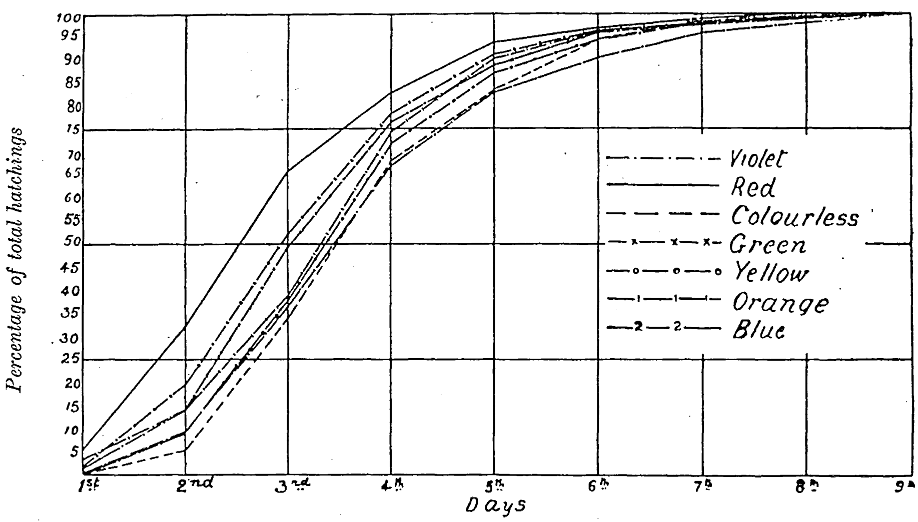

FIG. 5. Percentage of average total hatchings of *T. vaporariorum* eggs under coloured screens, 1937-38.

b. *Duration of the nymphal stage.*

(1) *A. proletella.*—The duration of the nymphal stage was calculated from the date of hatching of eggs to the emergence of the adults. However, the duration up to the emergence of the first adult being a constant factor in all cases under each experiment, was discarded while summarising the data with a view to representing the daily emergence, their progressive totals and the respective percentages (Table VI). The nymphal stage, therefore, may be calculated by adding the number of days before emergence (Table VII) to the duration of emergence in the respective cases. The relative influence of the various screens is further shown in Fig. 6. The duration of nymphal stage under the various screens was influenced

TABLE VI. *Average daily emergence, accumulative totals and percentage of totals emergence of the adults of* A. proletella *under different coloured screens*, 1937-1938.

Colour of screen	Emergence	Days from the commencement of emergence of the adults											
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Violet	(A)	0	1.8	5.0	6.5	8.5	3.3	3.8	4.5	3.5	4.0	2.0	1.0
	(B)	0.	1.8	6.8	13.3	21.8	25.1	28.9	33.4	36 9	40.9	42.9	43.9
	(C)	0.0	4.1	15.5	30.3	49.7	57.3	65.9	76.2	84.0	93.1	97.7	100.0
Red	(A)	1.8	6.5	8.3	6.0	4.5	3.3	2.3	2.0	0.5	0.8	—	—
	(B)	1.8	8.3	16.6	22.6	27.1	30,4	32.7	34.7	35.2	36.0	—	—
	(C)	5.0	23.1	46.1	62.8	75.2	84,4	90.9	96.4	97.8	100.0	—	—
Colourless	(A)	0	0.8	1.8	2.3	4.0	5.0	3.3	5.8	5.5	3.3	3.0	0.5
	(B)	0	0.8	2.6	4.9	8.9	13.9	17.2	23.0	29.5	31.8	34.8	35.3
	(C)	0.0	2.2	7.3	13.9	25.2	39.4	48.7	65.1	80.7	90.1	98.6	100.0
Green	(A)	0.3	1.8	3.8	4.0	4.0	2.8	2.5	2.3	2.5	0.3	1.0	—
	(B)	0.3	2.1	5.9	9.9	13.9	16.7	19.2	21.5	24.6	24.3	25.3	—
	(C)	1.2	8.3	23.3	39.1	55.0	66.0	76.0	85.0	94.9	96.0	100.0	—
Yellow	(A)	0.5	0.0	2.3	2.8	5.5	4.8	3.8	6.0	4.8	2.5	2.5	0.3
	(B)	0.5	0.5	2.8	5.6	11.1	15.9	19.7	25.7	30.5	33.0	35.5	35.8
	(C)	1.4	1.4	7.8	15.6	31.0	44.4	55.0	71.8	85.2	92.2	99.2	100.0
Orange	(A)	1.0	3.5	3.8	4.8	5.5	3.5	2.0	2.0	1.8	2.0	1.5	—
	(B)	1.0	4.5	8.3	13.1	18.6	22.1	24.1	26.1	27.9	29.9	31.4	—
	(C)	3.2	14.3	26.4	41.7	59.2	70.4	76.8	83.1	88.8	95.2	100.0	—
Blue	(A)	0	1.3	4.3	2.0	6.0	5.8	4.8	3.0	3.0	2.3	1.3	—
	(B)	0	1.3	5.6	7.6	13.6	19.4	24.2	27.2	30.9	32.5	33.8	—
	(C)	0.0	3.8	16.6	22.5	40.2	57.4	71.6	80.5	89.3	96.1	100.0	—

REMARKS—Emergence of the adults seems to extend over a relatively longer period under the colourless, violet and yellow screens. On an average, the shortest duration of nymphal stage was calculated under the red screen.

A. Average emergence. B. Total emergence. C. Percentage of total emergence.

practically in the same manner as the egg stage, and hence the conclusions are almost identical.

The percentage of the earliest emergence, on an average, is higher under the red screen than under any other screen (Table VI). At the same time, the peak of maximum emergence of the adults on any one day, as well as the limit of over 50% of the total emergence, is relatively earlier under the red screen than in others.

TABLE VII. *Emergence of the adults of* A. proletella *under different coloured screens,* 1937-1938

Colour of screen.	Average duration of emergence (in days) calculated from the commencement of emergence under any colour — Number of experiments each with three replications				Mean.
	I	II	III	IV	
Red	4.90	3.86	4.73	3.28	4.19
Orange	5.70	6.95	4.60	4.41	5.42
Green	5.93	6.10	5.68	4.78	5.62
Blue	6.80	6.91	6.58	4.77	6.26
Violet	7.00	6.65	6.33	5.25	6.31
Yellow	5.17	8.41	7.38	5.73	6.67
Colourless	6.04	8.62	8.50	6.07	7.31

Standard error ± 0.432. Significant difference 1.296
Remarks. Duration from hatching of eggs to the emergence of first adult in experiment:—
1. 21 days, 2. 24 days, 3. 26 days, 4. 25 days.

The relative grouping of the effect under different screens was equally defined and the trend of the curves (Fig. 6) was almost similar to that for the egg stage ; the effect of the red screen indicating the shortest duration of the nymphal stage. Next in order, follow the results under the orange and green which take the middle position. The third group, constituted by the results of the other screens, indicated the longest duration under their influence. The position of the blue, however, was slightly shifted from the second to the third group.

The standard error calculated from the results of these observations was ± 0.432 (Table VII). The effect of the red screen was significantly different from those of all others except the orange. At the same time the effect of the orange or green was significantly different from that of the colourless but not from others, although they show slight indications

towards it. The differences between the results of the constituents of the third group, however, were not significant. Moreover, the emergence of the adults extended over a relatively longer period under the colourless, violet and yellow screens.

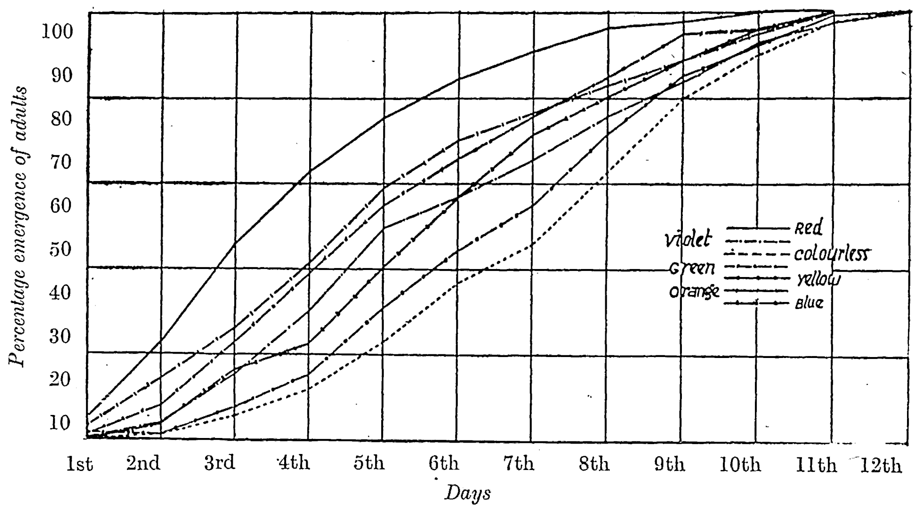

FIG. 6. Percentage of average total emergence of the adults of *A. proletella* under coloured screens, 1937-38.

(2). *T. vaporariorum.*—On the whole, the general effect of various screens was almost similar to that observed in the case of *A. proletella*. The percentage of the earliest emergence of adults, on an average, was relatively higher under the red screen than under any other. At the same time, the peak of the maximum emergence on any one day, as well as the limit of over 50% of the total emergence was relatively earlier under the red screen than under any other.

The relative grouping of the effects under various screens in this case also follows a trend almost similar to the one observed in *A. proletella*. The effect of the red screen at one extremity indicated the shortest duration of the nymphal stage. Next in order were the green and orange taking up the middle position. In this case, however, their respective positions were reversed when compared with that in the previous example. The third group included the effect of the rest of the colours, showing relatively longer duration. A little overlapping of the effects of blue and violet screens at the commencement of emergence of adults, indicates the shifting of the blue from the middle to the third group as already noticed in *A. proletella*.

The standard error calculated from these data is $\pm$ 0.176. The effect of the red screen shows quite significant differences from all others. The differences between green and orange were not significant, as also noticed

in *A. proletella*, but their results were significantly different from those of the other screens. Blue showed a slightly doubtful position and was more towards the violet. The difference between the yellow and colourless is not significant.

As noticed previously, the emergence of adults extended over a relatively longer period under the colourless, yellow and violet screens.

VI. Discussion of the results

The behaviour of the two species of white-flies studied with respect to their oviposition and development, under different coloured screens, requires some explanation. As the use of the cellophane screens does not, in any way, ensure the monochromatic radiations which form the spectrum, there is no reason to believe that the relative effect of these screens will show any correspondence to the order of the colours manifested in the spectrum. Hence, the effect is likely to be interpreted in terms of wave-lengths of light which are transmitted or cut off, by the intervention of these screens (Fig. 2). Moreover, the relative intensity of the radiation transmitted through these screens (Table I) may have some appreciable effect on the reproductive phases. On this hypothesis, the following suggestions are offered :

Relative oviposition.—The most favourable effect of the yellow and the colourless screens may be dependent on their relatively higher transparency. Lloyd (1922) stated that the adults of the green-house white-fly, are attracted to yellow colour. Our knowledge of *Bemisia tabaci* (*-gossypiperda*) in the Punjab (Husain and Trehan, 1933) as well as the observations on other species (Trehan, 1939 and 1940), have shown, that a relatively larger number of adults and eggs are met with on the top leaves or at any rate, those that are much exposed to light. This fact, coupled with the results of Lloyd, affords a possible explanation that the intensity of light and particularly the yellow tinge at that region, attracts the adults thus resulting in a higher oviposition.

Further, the medium and long waves appear to have some stimulative effect as compared with the retarding effect of the short waves. It may, however, be pointed out that the red screen does not show the stimulative effect, most probably because, it also lets through a certain amount of the extreme short waves, which very probably counteract its effect. Yellow, on the other hand, lets all the long wave lengths to pass, particularly the medium ones, and at the same time almost cuts off the short blue rays. Thus, the effects of the long and medium waves become very much pronounced.

Duration of the egg stage.—The development was comparatively most rapid under the red screen. It is, therefore, presumed that the rays cut off

by this screen, have a particularly retarding effect on larval development. Yellow practically works like the colourless. The violet has a retarding influence because through it the absorption in the middle region of the spectrum is comparatively low, and, therefore, it does let through some of the rays which retard the development.

Green is not retarding to the same extent as the yellow or violet, because, although it cuts off the blue to some extent, it also transmits a portion of the rays of higher wave lengths than 600 Angstrom units.

Orange is quite towards the red as it cuts off a greater part of the medium wave lengths.

Blue shows relatively a little stimulative effect, since it cuts off a portion of the wave little below 600 and thus reduces the green.

It may, therefore, be safely stated that the retarding effect is probably brought about by the middle portion of the spectrum lying between 500-600 wave lengths.

TABLE VIII. *Mean duration of the egg stage of* A. prolettela *under different coloured screens in relation to the intensities of light.*

Colour of Screen	Mean duration (in days)	Percentage intensity of light.	Mean duration corrected for intensities
Red	11.81	47.6	12.23
Orange	12.66	69.2	12.59
Green	12.64	67.4	12.61
Blue	12.59	52.6	12.90
Violet	13.49	57.1	13.70
Yellow	13.12	76.7	12.88
Colourless	13.34	92.1	12.76

S. E. $\pm$ 0.178

The stimulative effects of the red and blue also suggest that the relatively low transparency under these screens might as well be a contributive factor in affecting the rapid development. This, however, is almost within experience because, it has been observed in nature that the immature stages of white-flies always predominate in the middle region of the host plant and out-number those which are found in any other part. The shade in such circumstances probably encourages a quick development.

Some experimental evidence in this respect, however, may be noticed from the figures of the egg stage in *A. proletella*, when the mean durations are corrected for the intensities as given in Table VIII. These corrected figures result in slightly smoothening down the arrangement of the colours. Thus, the corresponding intervals were more or less in the spectral order, except that the yellow and green change their respective positions.

Duration of the nymphal stage.—The above explanation also throws light on the observations on the duration of nymphal stage under the influence of various screens. Still, as the effect of the blue screen in this case shows a slight shifting of the curve towards the violet, yellow and colourless, it seems likely that the retarding effect extends over a wide range towards the shorter wave lengths and may be roughly from 450-600.

VII. Summary and Conclusions

Since the relationship between insect multiplication and the spectral components of light deserve some investigation, the problem was taken in hand with two common species of British white-flies, namely, *Aleurodes proletella* Linn. and *Trialeurodes vaporariorum* (Westwood).

The technique adopted in carrying out these experiments is described.

The results have shown that oviposition is highest under yellow screen; the colourless and violet approaching very near to it in this respect.

The shortest durations of the egg and nymphal stages are noticed under the red screen against the longest duration under the colourless, yellow and violet. The orange, green and blue screens are intermediate. The emergence of adults, on an average, is spread over a longer period under the yellow, colourless and violet screens.

The results of the present investigation are in general harmony with Kogure's conclusions. In all these experiments, the effect of the red screen has been invariably distinct and its position formed one extreme. The colourless, yellow and the violet have been always near one another. Their association has been confirmed even in their divergent effects as noticed separately under oviposition and development. Orange, green and even the blue maintain the middle position.

It is concluded that the retarding effect is probably brought about by the middle portion of the spectrum and extends roughly between 450-600 wave lengths. Taking the spectrum as a whole, it has been observed that none of the coloured screens has been, in any way, totally detrimental to the insect multiplication. It is, however, presumed that the results of the various coloured screens are manifested by the combined effects of the wave lengths and the relative intensity of light transmitted through them.

VIII. Acknowledgments

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SHORT NOTES AND EXHIBITS

A fresh cycle of the desert locust in India

I reported in this Journal last year [2 (2) : 241, 1940] that a fresh cycle of the desert locust had started in India in the last autumn. The situation up-to-date (15. IV. 41) is briefly described below:—

The swarms remained active up to the beginning of January, 1941. The last report was from the Loralai district of Baluchistan. A thorough survey of the various areas in north west India, which had been visited by the swarms, was made during the winter to determine the localities where locusts were overwintering. It was found that the locust overwintered in appreciable numbers in the coastal areas of Baluchistan (Mekran) and the interior of Kachhi and Jhalawan parts of the Kalat State. There was a slight concentration in the Bikaner State in Rajputana also. There was a thin population in all the other desert areas. The highest population observed in Mekran was about 26,000 per sq. mile, whereas in Kachhi it was 80,000 per sq. mile. In the spring, the locust became active again and a large number of females were destroyed in the areas mentioned above. The survivors laid eggs and hoppers were noticed early in March in appreciable numbers on Gwadar reks and in cultivated fields near Suntsar in Mekran. In Kachhi area, hoppers appeared about the end of March. About 50% of the advanced stage were of gregarious phase. Suitable control measures were taken to destroy the hoppers to prevent incipient swarming.

Light spring-breeding also took place in Bikaner and suitable measures were taken to destroy the pest. It is also of interest to record that locust-breeding also took place in the Muscat State in Arabia and adult locusts migrated into Mekran in March, thus augmenting the original population of the locust in that area.

New Delhi HEM SINGH PRUTHI

A biological note on *Chilomenes sexmaculata* Fabr.

The writer studied the life-history of *Chilomenes sexmaculata* Fabr., a well known predator of *Aphis laburni*, *Aphis gossypii*, *Rhopalosiphum pseudobrassicæ*, *Macrosiphum granarium*, *M. solidaginis*, and *Aphis maidis* at constant temperatures of 50°F., 64°F., and 77°F., and at room temperature (mean being 68°F. from 15th January to the end of February, 1941).

The adults copulated 3-4 days after emergence and unless the beetles were fully fed they did not copulate. The duration of copulation varied from half an hour to two hours and was repeated at frequent intervals before the female began to oviposit. The pre-oviposition period was about six hours. The maximum number of eggs laid by a single female over a period of seven days was 231 ; the number of eggs laid at one time being 43-108. The average duration of adult's life varied from 7 to 14 days. Starved beetles lived for 4 days only. The average number of aphids (*Macrosiphum granarium*) eaten by the adult per day was 44. The beetles neither fed well nor oviposited at constant temperatures of 50°F., or 64°F.

The cigar-shaped eggs were laid singly or in longitudinal rows, varying from 4 to 14 in each. The incubation period was 1 or 2 days at 77°F. and 3 to 5 days at room temperature.

The larval life occupied 10 to 12 days at 77°F. and 13 to 15 at room temperature (average of 12 observations). The grub underwent three moults. The number of aphids (*Macrosiphum granarium*) eaten by a grub was 456 at 77°F. and 310 at room temperature (average for 12 grubs). The grubs, however, did not survive for more than 4-5 days at temperatures below 64°F.

The pre-pupal stage lasted for 24 to 36 hours, and the pupal stage for 4 to 6 days at room temperature and 3 to 4 days at 77°F. The whole life-cycle took 17 to 20 days at a constant temperature of 77°F., and 23 to 30 days at room temperature. If food was scarce, the beetles and the grubs exhibited cannibalistic tendencies.

New Delhi C. N. MODAWAL

A note on two species of Embioptera from Delhi

The writer recently collected two species of winged Embiids, *Parembia valida* (Hagen) and *Oligotoma nigra* Hagen, from Delhi. *P. valida* was collected on wing towards the evening and O. *nigra* at light.

The first record of *P. valida* was a female specimen from Ambala collected by the Rev. C. C. Carleton, and provisionally described by Hagen as *Oligotoma valida*. McLachlan (*Zool. Rec.*, 259, 1883,), however, believed this to be the female of *Oligotoma michæli* McLachlan. Hagen, in his monograph of Embiids (*Canad. Ent.*, **17** : 150,1885), accepted this view. Davis' recent re-examination of the specimen preserved in the Museum of Comparative Zoology, Harward College, has revealed that it is not *O. michæli* McL., but is conspecific with *Embia major* Imms (*Trans. Linn. Soc. London*, **11** : 167-195, 1913). He, therefore, holds [*Proc., Linn. Soc. N. S. Wales*, **64** (5-6) : 474-482, 1939] that Imms' *major* will have to be replaced by Hagen's *valida*. Davis erected a new genus, *Parembia*, for the three Asiatic species of *Embia* and this species should now be called *Parembia valida* (Hagen).

P. valida has so far been recorded from Kumaon hills and Ambala. The present record extends its range to Delhi. Further, it is interesting to note that Needham's figure of *Embia* sp. from Rameswaram (*Rec. Indian Mus.*, **3** : 193, pl. 20, fig. 13, 1909) agrees with *P. valida*.

So far, the only record of *O. nigra* from India is a male specimen collected from Ambala by Rev. C. C. Carleton, identified by Hagen as *O. michæli* McL. Its correct identity was revealed by Davis.

O. nigra Hagen has been recorded from California, Arizona, Egypt, Arabia, Palestine, Iraq and India (Ambala only). The present record confirms its distribution in India. Needham's figure of *Embia saundersi* (*Rec. Indian Mus.* **3**, pl. 20, fig. 11, 1909) agrees with *O. nigra* Hagen. The locality of this insect, is not given by Needham, but Annandale remarks in a footnote that this species is often found in Calcutta at night on white-washed walls illuminated by lamps.

New Delhi R. MENON

New host plants of some Indian insects of economic importance

The following is a list of host plants of some important insects observed at Delhi during the past three years and not recorded so far from India:—

Name of insect	New food-plants	Season
ARCTIADAE		
Utetheisa pulchella (Linnæus)	*Heliotropium eichiwaldii, Heliotropium undulatum, Trichodesma indicum*	Winter
NOCTUIDAE		
Laphygma exigua (Hübner)	*Basella rubra.*	Autumn
	Digera arvensis, Ipomea pestigridis, Commelina bengalensis, Tribulus terrestris, grape-vine, plum, almond, *Trichosanthes dioica,* groundnut.	Summer
	Avena sativa.	Winter
Tathorhynchus exsicatta Leverer	*Phaseolus radiatus*	Summer
Anticarsia irrorata (Boisduval)	*Vigna catjang, Phaseolus mungo.*	Summer
Amyna octo Guenee	Apple, *Digera arvensis, Vigna catjang.*	Summer
Anomis involuta (Walker)	*Medicago sativa.*	Autumn
Mocis undata (Fabricius)	*Medicago sativa.*	Autumn
Heliothis peltigera Schiffermiller	*Ocimum sanctum*	Summer
Eublemma parva (Hübner)	Safflower	Winter
LYMANTRIADAE		
Dasychira securis (Hübner)	*Luffa aegytiaca, Sesamum indicum.*	Summer
Lælia testacea Walker	Castor	Autumn
Euproctis varians Walker	*Vigna catjang*	Summer
PYRALIDAE		
Phlyctaenodes nudalis (Hübner)	Brinjal	Autumn
Dichocrocis punctiferalis (Guenee)	Hollyhock	Autumn
LYCAENIDAE		
Zizera lysimon (Hübner)	*Tribulus terrestris*	Summer
SPHINGIDAE		
Celerio lineata (Esper)	*Thevetia neriifolia*	Autumn
ANTHOMYIDAE		
Atherigona bituberculata Malloch	*Paspalum sanguinale*	Summer

New Delhi MOHAN SINGH

"Indian J. Ent., 3 (1)"

Aspidiotus destructor a pest of mango at Jammu (Kashmir)

Aspidiotus destructor Sign. recently appeared as a serious pest of mango seedlings in several nurseries at Jammu. This scale-insect has been previously reported from several parts of the world, chiefly as a pest of coconut.

At Jammu, the female scale lays about thirty eggs, the nymphs hatching therefrom crawl over or are carried by wind to healthy plants. Infestation takes place mostly on the underside of mango leaves. The scale insects are most active during summer, and hibernate during winter. The most effective control measure for this pest is spraying the infested plants with kerosine-oil emulsion about the end of November. Removal of slightly infested twigs is also useful. Natural enemies, some Chalcidoid parasites, take a fairly heavy toll of the pest, but do not appear to effectively check its spread in nature. A local variety of mangoes, viz., *kattha*, is not much attacked by this species.

Srinagar R. M. FOTIDAR AND A. P. KAPUR

Tonica niviferana Walker (Oecophoridæ) in the Punjab

A few larvæ of *Tonica niviferana* were found damaging leaves of silk-cotton tree (*Bombax malabaricum*) in the month of March. This is probably the first record of this species from Lyallpur.

Lyallpur KHAN A. RAHMAN

Pediculoides ventricosus Newport, as a parasite of *Platyedra gossypiella*

The double seeds of cotton obtained from Ludhiana (Punjab) for pink bollworm studies were found to be invariably infested by this parasitic mite. Because of the attack of this mite, the pink bollworm larvæ of at first become sluggish, gradually shrivel and die. The mite thrives best at 27°C., and thus proves a great nuisance in breeding pink bollworm larvæ. This is also injurious to the larvæ of *Chilo simplex*, but those of *Sylepta derogata* are comparatively immune. At room temperature at Lyallpur the mite dies off by the end of April or beginning of May.

Lyallpur A. N. SAPRA

Observations on *Silvanus surinamensis* Linn. (Cucujidæ)

This species is commonly found in the Punjab, infesting stored products such as dates, apricots, grapes, figs, melon, maize, *jowar*, rice and wheat.

The freshly laid eggs are white in colour and take 7-9 days to hatch. The yellowish-white larva undergoes 4-5 moults and is full grown in about 36 days. Pupal stage occupies a week. The adults live for 2-5 months. A single female lays as many as 85 eggs. Oviposition period in some cases is as long as two and a half months. The larvæ are parasitized by *Cephalonomia tarsalis* Ashm.

Lyallpur GURCHARAN SINGH SOHI

Psorosticha zizyphi as a pest of *Citrus* in the Punjab.

Larvæ of *Psorosticha zizyphi* stainton were reported doing damage to *Citrus* plants in the nursery at the New Seed Farm, Sargodha during 1940. The larvæ feed inside rolled leaves of young plants. This is the first record of this species in the Punjab. Two hymenopterous parasites were bred from the larvæ.

Lyallpur M. A. GHANI

Some host-plants of *Phytomyza atricornis* (Meig.) in the Punjab.

In addition to the hosts already recorded in this Journal [2 (1) : 95, 1940,] this species has been reared from the following plants at Lyallpur:—

Pisum sativum ; *Sonchus asper*, *Sonchus oleraceus* *Brassica rapæ* ; *Launæa aspleniifolia* ; *Gaillardia* sp. ; *Melilotus parviflora* ; *Chrysanthemum* sp. and *Malva parviflora*.

Lyallpur M. A. GHANI

RECENT RESEARCH

Insect outbreaks in Europe

Carpenter (*J. Anim. Ecol.*, 9 : 108-47, 1940) has used a very ingeneous technique for studying the fluctuation trends of insect-population of Europe. A large number of insect-outbreak records of Europe have been examined to determine if the outbreaks can be regarded as normal fluctuations in population numbers, considering the individuals of all species of a large area as members of one population. The data for the different natural vegetation regions of Europe were separately analysed and those of the deciduous forest area, owing to their huge size and number, were further sorted out for smaller regions, into which this area could be divided. After sorting out, classifying and weighing these data to a certain extent on the basis of comparative importance, the total number of annual outbreak records in one biogeographic unit has been used as an index of population level for the year. This index, plotted against time abscissa for each region or sub-region separately, showed a striking general agreement in the fluctuation patterns. Although each region shows certain individual characteristics, a remarkable synchronism is apparent in certain master trends, showing a general reaction in time of the entire insect-population of the continent as a whole. However, no regular periodicity is evident and the major species mainly responsible for the peaks differ from peak to peak and region to region. S. P.

Influence of hosts on parasites

There is a considerable amount of literature on the influence of parasites on hosts, but the problem of the influence of hosts on parasites has received some attention only recently. In 1936, Marchal (*Ann. Epiphyt. Phytogen.*, **2** : 447-550) showed that *Trichogramma cacœciæ* is so much influenced by its host, *Cacœcia rosana*, that its emergence is delayed by 7-8 months. A year later, Salt (*Parasitology*, **29** : 539-553) noted that the host, *Sialis* so intimately affected its parasite, *Trichogramma semblidis*, that it completely altered the facies of its male sex. Recently, Salt (*Proc. R. ent. Soc. London*, **15** : 81-95, 1940) has studied the influence of *Sitotroga*, *Ephestia* and *Agrotis* on *Trichogramma evanescens* and observed that the size, vigour, fecundity, longevity and rate of development of this parasite are affected by the respective hosts. Further, the host, through its effects on the size of the parasite, influences the behaviour of the female parasites in selecting hosts for their progeny. This raises a matter of fundamental importance with regard to the conception of biological constants. The study shows that in the case of *Trichogramma* and probably also other parasites, the host is one of the effective characters and must be studied before the biological constants relating to the parasites can have any general validity.

H. S. P.

Sunspots and insect outbreaks

Sunspot number is a relative figure obtained by an arbitrary formula indicating solar-spottedness from time to time, with the help of which it is possible to identify epochs of maximum and minimum solar activity. It is believed by some workers that fluctuations in numbers of animals are associated with numbers of sunspots. MacLagan [*Proc. Univ. Durham phil. Soc.*, **10** (3) : 173-99, 1940] has studied the correlation between sunspot numbers and insect incidence in the case of six species. The data have been collected from all the available past records of major insect outbreaks in Britain. The average of the intervals between successive outbreaks of a species comes to about eleven years, which shows a striking parallelism to the well established 11-year sunspot cycle. The majority of the insect outbreaks are found to have occurred within 5-year periods, commencing 3 years previous to the sunspot maxima and ending one year after it. This crowding together of epidemics within 5-year periods is significantly different from what can be expected on the basis of random chronological distribution of epidemics. Moreover, each species shows its own specific phase-relationship to the sunspot maxima, indicating the variety of ecological conditions presented by the environment in the different phases in the cycle of solar spottedness.

The author tries to seek the explanation for these correlations, in a combination of some general climatic pulsations and variations in some little-known factors concerning quality and quantity of solar radiations which appear to be associated with sunspot cycle.

S. P.

On the physiology and toxicology of blowflies

Although considerable work has been done on insect nutrition, practically little is known concerning the details of digestion or the absorption of digested food-products. Similarly, the influence of the hydrogen-ion concentration of the gut-contents on digestion and absorption, including the absorption of the stomach poisons remains obscure. Recently some very interesting work has been done on the blowfly, *Lucilia cuprina* by Lenox and Waterhouse (*Coun. Sci. industr. Res. Australia*, **90**, 1939; **101** and **102**, 1940). The object of their studies was to discover substances that may be used in the treatment of 'strike', to elucidate the mechanism of action of poisons, and the mode of their application.

A synthetic medium for the aseptic breeding of the larvae consisted of yeast, sodium chloride and agar or the white of an egg. The measurement of the growth of the larvæ was done photographically, as they were being reared in flat-walled bottles. The action of certain stomach-larvicides showed that the growth-retarding influence of the poison is diminished by the increase in the nutritive properties of the synthetic media. The rate of mortality of partly grown larvae, after transferring them to poison-impregnated media indicated that the mortality-rate increases with concentrations of poisons, but decreases with the age of the larva. Growth retardations are compared with the mortality rate for measuring the stomach toxicity by using a number of chemicals. Nicotine, pheno-thiazine and arsenic, as well as selenium compounds proved most toxic. Methelene blue and a variety of dye stuffs of tri-phenyl-methane group were most effective.

The toxicity of some arsenicals to the larvae showed that they could be divided into two groups in order of decreasing toxicity. The highly toxic compounds included barium arsenite, calcium arsenite, arsenic acid, paris green and arseneous oxide, while arsenates of zinc, aluminium, lead and calcium were moderately toxic. The action of contact larvicides, inorganic acids and alkalis seems to depend on their hydrogen-ion and hydroxyl-ion concentrations respectively.

Aliphatic halogenated and aromatic hydrocarbons are exceptionally potent, and in the normal aliphatic alcohols or fatty acids the toxicity increases as the carbon chain lengthens within the homologous series. Isomeres of alcohols and acids are less toxic than corresponding normal compounds. Aqueous solutions of free base nicotine are considerably more toxic than solutions containing nicotine as sulphate. Of essential oils, caraway, dill, mustard, thyme, etc., are most toxic. Lipoid solvants are highly toxic, as they are thought to function by dissolving the outermost cuticular layer.

The alimentary canal of nine species of blowflies showed, that in the larvae the hydrogen-ion concentration of the gut-contents was the same as that

of the medium on which they were grown. In the adults the hind gut-contents were more acidic than in the larvæ.

In the larvae of a number of species, the absorption of iron occurs in a region which has fairly constant pH range. In the prepupal and pupal periods, iron is transferred to nephrocytes, fat bodies, and developing wing-and leg-rudiments. In the adult, iron accumulates in fat bodies and later appears in the oocytes during the earlier stages of egg-development, but disappears at maturation. Throughout development, the iron-concentration remained approximately constant between 3 and 4 milligrams per cent of live tissue. P. J. D.

Termite intercastes

Besides the normal alate reproductives, soldiers and workers, certain individuals known as 'Intercastes', are sometimes found in a termite colony. Such intercastes have been recorded in some species of Kalotermitidae, in *Reticulitermes tibialis* Banks (Rhinotermitidae), *Nasutitermes* (*Nasutitermes*) *myersi* Snyder, and *N.* (*N.*) *similis* Emerson (Termitidae). The intercastes are mostly members of one caste, possessing a few unimportant features of another. For example, they may be soldiers with wing-buds (reproductive-soldier intercastes) as in the Kalotermitidae or forms combining the characters of soldiers and workers (soldier-worker intercastes) as in the above-mentioned species.

Adamson's recent records [*Proc. R. Soc.*, (B), **129** (854) : 35-52, 1940] of two cases of intercastes in *Nasutitermes* (*Nasutitermes*) *guayanæ* (Holmgren) and *Microcerotermes arboreus* Emerson (Termitidae) are of great interest, in view of the fact that such intercastes are so far known to occur only in the primitive Kalotermitidae only. According to him, the intercaste of *N.* (*N.*) *guayanæ* appears to be so unique in the possession of several important characters of two castes, that it cannot be readily assigned to one or the other. Its head is predominently that of a nasute soldier, but it bears the compound eyes and ocelli of the reproductive caste, the characters of which predominate in the thorax and abdomen. The two specimens of intercastes of *M. arboreus* are soldiers, with rudimentary wings and with the vestigial compound eyes more highly developed than in a normal soldier.

These rare types of termite intercastes are believed by Adamson to have been produced under peculiar environmental influences and are not due to changes in genetical constitution. The author also supports the views of Emerson and others that the worker caste arose phylogenetically from the soldier and not directly from the reproductive caste. R. M.

A biological campaign against prickly-pear

One of the most remarkable examples of biological control of a weed is that of the phenomenal control of the prickly-pear weed in extensive

areas of N. E. Australia by the use of some beneficial insects, especially the moth, *Cactoblastis cactorum* Berg. The campaign was started in 1921 and has been in progress for about 20 years. Dodd (*Herbage publ. Ser. Bull.*, **27** : 131-143, 1940) has recently described all the steps which contributed to the success of the control methods.

The problem of prickly-pear in Australia can be stated briefly as that of a vigorous, rapidly spreading weed, occupying very large tracts of grazing country, where mechanical and chemical method of eradication were economically impracticable. Of the different species of the weed, *Opuntia inermis* and *Opuntia stricta* assumed major status and from 1908 onwards they spread very rapidly, occupying roughly 60 million acres in 1925. From 1921 onwards numerous insect enemies were introduced, including the moth borer *Olycella*, the plant-sucking bug *Chelinidea* and the Cochineal *Dactylopius*. In 1925, the moth *Cactoblastis castorum* was introduced and mass-scale rearing of it was started. Since 1928 the moth had multiplied rapidly and the general destruction of the prickly-pear started. By about 1940 the major prickly-pear pest was almost completely controlled and extensive areas reclaimed and brought into production. The conquest of prickly-pear has been due almost entirely to this remarkable insect. Its introduction brought complete change in the outlook within a few years. Its progress has been spectacular ; its achievements border on the miraculous. Great tracts of country, utterly useless on account of dense growths of the weed, have now been brought into production. The prickly-pear territory has been transformed, as though by magic, from a wilderness to a scene of prosperous endeavour.

Cactoblastis cactorum is a native of Argentine and the adjacent parts of S. America. The larvae are gregarious, tunnelling in the segments and stems of prickly-pear, and reducing the plants to a rotting mass. One consignment only containing 2750 eggs was introduced into Australia, from Argentine in March, 1925. After being reared in cages through two generations, the small original number had multiplied to 2,540,000 by March, 1926.

This interesting publication gives a very good idea of the various factors influencing biological control measures for different pests, both plant and animal.

T. V. R.

NEW BOOKS AND MONOGRAPHS

The Francis Walker types of Trichoptera in the British Museum. By Cornelius Betten and M. E. Mosely. Pp. ix+248. London : British Museum (Natural History), 1940. Price 15s.

A general Zoology of the Invertebrates. By G. S. Carter. Pp. xxxviii+509 ; 13 pls., 172 figs. London: Sidgwick & Jackson, 1940. Price 25s.

Entomophagous Insects. By C. P. Clausen. London : Mc-Graw-Hill Book Co., Inc. 1940. Price $7.00.

Plant Galls and Gall Makers. By E. P. Felt. Pp. viii+364 ; Pls. 41, figs. 344. New York: Comstock Publishing Co., Inc., 1940. Price $4.00.

Fleas of Eastern United States. By Irving Fox. Pp. vii+191 ; pls. 31, figs. 166. Iowa : 1940. Price $3.00.

Insect Pests of Burma. By C. C. Ghosh. Pp. xv+216. ; 87 pls. Rangoon : Government Printing and Stationery, Burma, 1940. Price Rs. 5-10.

The Orientation of Animals. By S. Gollfried et al. Pp. viii+352 ; pls. 10. Oxford : 1940. Price 21s.

Insect Pests in Stored products. By H. Hayhurst. Pp. xii+83 ; 49 pls. London : Chapman & Hall, 1941. Price 15s.

New Bilingual Catalogue of the British Lepidoptera. By I. R. P. Heslop. Pp. 132. Cambridge: W. Heffer & Sons, 1940. Price 6s.

Evolution : The modern synthesis. By Julian Huxley. London : G. Allen & Unwin, 1941. Price 7s. 6d.

Embryology of Insects and Myriapods. By O. A. Johannsen and F. H. Butt. London : McGraw-Hill Book Co. Inc., 1940. Price $5-00.

Insect Pests of Farm, Garden and Orchard. By L. M. Pears. (Fourth edition). New York : John Wiley & Sons, 1940. Price $4.00.

The Virus : Life's enemy. By Kenneth M. Smith. Pp. viii+176 ; 9 pls. Cambridge : University Press, 1940. Price 7s. 6d.

The Male Genitalia of Hymenoptera. By R. E. Snodgrass. *Smithsonian Misc. Coll. Publ.* No. 3599. Pp. 86 ; pls. 33. Washington : Smithsonian Institution, 1941.

Compendium of entomological Methods. Part 1. Collecting Mayflies (*Ephemeroptera*). By J. R. Traver. Pp. 8, illus. New York : Rochester, Ward's Natural Science Establishment, Inc., 1940. Gratis.

The Fauna of British India. Diptera. Vol. 6: Family Calliphoridæ. By R. Senior-White, Daphne Aubertin and John Smart. Pp. xiii+288. London : Taylor & Francis, Ltd., 1940. Price 18s.

Animal Biology. By Robert H. Wolcott. (Second edition). Pp. xxi+649. London : Mc-Graw-Hill Book Co., Inc., 1940. Price 24s. 6d.

INSECT PESTS OF BURMA

Mr. C. C. Ghosh has rendered valuable service to agriculture in Burma by publishing a treatise on the common insect pests of that country, indicating the methods for their control. This book is based on Mr. Ghosh's fifteen years' experience in Burma and on nine years' work of his predecessor, Mr. Shroff. A very useful and important feature of the book is the numerous colour plates, which illustrate the nature of damage and life-histories of various pests. Almost all the colour illustrations are reproductions of those originally published by the Imperial Agricultural Research Institute, Pusa (now at New Delhi).

The book is admittedly meant for general readers, students and educated cultivators. Serious students of entomology should not, therefore, complain

if they find numerous errors of academic interest. Very few entomologists now follow the Linnæan system of insect classification advocated in 1758, which has been adopted by Mr. Ghosh. Further, in the case of several genera and species, the names given are those which were discarded long ago, *e. g.*, *Ripersia* instead of *Trionymus* (p. 87), *Agromyza* instead of *Melanagromyza* (p. 105), *Pectinophora* instead of *Platyedra*, etc., etc. On page 7, the word "aphis" has been used for all aphids, whereas actually *Aphis* is a distinct genus in the family. In some cases, scientific names have been omitted altogether. The generic nomenclature of the tobacco leaf-caterpillar is followed differently in the description and its illustrations.

We very much regret that the value of the book is marred by the carelessness on the part of the press. There are numerous press mistakes, as well as errors in proof-reading.

By pointing out the errors mentioned above, we have no intention of showing that the book is not valuable. We trust that the errors will be corrected in the next edition. The book forms a part of the useful series, of which Fletcher's "South Indian Insects" was the beginning, and we hope that entomologists of other provinces will also prepare similar accounts of the insects of economic importance of their areas.

H. S. P.

NEWS AND ANNOUNCEMENTS

Mr. P. V. Wagle has been appointed Acting Professor of Entomology, Agricultural College, Poona, *vice* Dr. V. G. Deshmukh on leave due to illness.

Dr. T. V. Ramakrishna Ayyar is engaged on the revision of H. M. Lefroy's "Handbook of Indian Crop Pests." He has been visiting several parts of India with a view to gathering up-to-date information about the control of various insect pests.

The Imperial Council of Agricultural Research have appointed a Standing Committee of Entomologists for considering all schemes dealing with insects.

Dr. Abdullah Shah, Ph. D. (Durham) has been appointed Second Assistant Professor of Entomology, Punjab Agricultural College, Lyallpur.

The Entomological Section of the Department of Agriculture, Baluchistan, has been revived.

Dr. K. B. Lal, M.Sc., Ph.D. (Edin.), Second Assistant Entomologist, Imperial Agricultural Research Institute, New Delhi, Secretary, Entomologial Society of India, during the past three years, has been appointed Entomologist to the Government, United Provinces, Cawnpore.

The Natural History Museum of Stanford University of California has started a new journal entitled "*Microentomology*", in which detailed external, morphological accounts of consolidated types are published. Five parts of the journal have already appeared.

We regret to record the following deaths:—

Dr. F. W. Edwards, M.A., Sc.D. (Cantab.), F.R.S., Entomological Department, British Museum, (Natural History,) London, on November 15, 1940. Born in 1888, started taking interest in insects at the early age of 4 under the influence of his mother. Educated at Cambridge throughout his educational career and started entomological studies under Dr. David Shaw and Sir Arthur Shipley. Joined the British Museum in 1910. Author of about 350 papers, and one of the foremost experts in the systematics of mosquitoes. Elected Fellow of the Royal Society in 1938.

Dr. C. W. Leng, on January 25, 1941. Age 81. Secretary, Entomological Society of New York for 18 years; Director of the Museum, Staten Island, New York, well-known for his catalogues on Coleoptera and some other groups.

PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF INDIA

Minutes of the third annual general meeting

The third annual general meeting of the Entomological Society of India was held at Benares on the 3rd January, 1941, at 2-30 P.M. In the absence of the President (Dr. Hem Singh Pruthi) Dr. N. C. Chatterjee, one of the Vice-Presidents, took the chair.

The minutes of the second annual general meeting held at Madras were read by the Secretary and confirmed.

A report on the working of the Society during 1940, including a statement on the financial position of the Society and the report of the auditor thereon, was read by the General Secretary and adopted unanimously (appended herewith).

The House discussed some modifications in the Rules of the Society, suggested by the President, the Chief Editor and the General Secretary, and submitted by the Executive Council with its own remarks for consideration.

The House accepted unanimously the following proposal by the President, and recommended by the Executive Council, for incorporation in the Rules :—

"The accounts of the Society shall be in the names of the General Secretary and the Treasurer and the latter would make payments endorsed by the General Secretary and the Managing Editor, respectively, in respect of bills not exceeding Rs. 10. Bills for sums in excess of this amount shall be jointly endorsed by the General Secretary and the President or the Managing Editor and the Chief Editor, as the case may be, before they will be valid for payment by the Treasurer. The General Secretary and the President will endorse bills pertaining to the administration and other general matters of the Society; the Managing Editor and the Chief Editor pertaining to the Society's publications."

The House unanimously accepted the following proposals by the Chief Editor and recommended by the Executive Council :—

"The President of the Society shall be ex-officio member of the Editorial Board.

The offices of the General Secretary and the Managing Editor shall be held by two individuals and the latter shall be elected by the Editorial Board from among its members.*

The number of members of the Editorial Board shall be raised from six to eight.

Interim vacancies in the Editorial Board shall be filled up by the remaining members of the Board itself as in the case of vacancies in the Executive Council."

The House unanimously accepted the following proposal by the General Secretary and recommended by the Executive Council :—

"The Executive Council may permit an Ordinary Member to hold his membership in abeyance for a specified period, during which he need not pay any subscription and will not receive the publications of the Society. On the resumption of his membership such a member will not have to pay any admission fee."

The House accepted by a majority the following proposal by the General Secretary (discussed and forwarded by the Council): —

* This rule has been kept in abeyance this year.

"The annual subscription payable by Ordinary Members shall be Rs. 10. The annua subscription of Fellows, if any, shall be Rs. 12/8."

The House unanimously accepted a recommendation of the Executive Council to the effect that the consideration of the question of "Fellows" shall be deferred to the annual general meeting of the Society in 1943.

The General Secretary read out the names of the following members who had been duly proposed and elected for the various offices of the Society :—

President for 1941	..	Dr. T. V. Ramakrishna Ayyar, Coimbatore.
Vice-Presidents for 1941-42	..	Dr. N. C. Chatterjee, Dehra Dun.
		Dr. Khan A. Rahman, Lyallpur.
General Secretary	..	Dr. Taskhir Ahmad, New Delhi.
Joint Secretary & Treasurer	..	Mr. H. L. Bhatia, New Delhi.
Councillors	..	Mr. J. C. M. Gardner, Dehra Dun.
	..	Mr. S. K. Sen, Mukteswar.
Members, Editorial Board	..	Mr. S. K. Sen, Mukteswar.
		Dr. K. B. Lal, New Delhi.

Dr. T. V. Ramakrishna Ayyar moved votes of thanks to the outgoing President, Dr. Hem Singh Pruthi, and to the outgoing General Secretary, Dr. K. B. Lal, for successfully carrying on the work of the Society during their tenures of office, which was unanimously carried.

General Secretary's report for 1940.

At the end of 1939, the total membership of the Society was 88 Ordinary, 2 Life and 2 Associate Members. During 1940, 19 Ordinary and 6 Associate Members were enrolled and an Honorary Member was elected. Three Ordinary and one Associate Members resigned their memberships of the Society and two Ordinary Members became Life Members. The total membership strength of the Society, therefore, at the end of 1940 was 1 Honorary member, 4 Life members, 102 Ordinary and 7 Associate Members.

The Society continued to maintain branches at Lyallpur, New Delhi, Pusa, Calcutta, Coimbatore and Karachi. Altogether 12 meetings were held under the auspices of the Society at its branch centres.

The *Indian Journal of Entomology* was published twice in the year as in 1939. Twenty-two institutions in India and fourteen abroad were registered as subscribers to the Journal. It is satisfactory to record that although the war caused serious strain on the resources of the Society in publishing the Journal, the size and standard of the publication as a whole and its various features remained unaffected.

The question of the election of Fellows of the Society, a resolution to which effect had been passed in the annual general meeting at Lahore, in 1938, was again postponed at the last annual general meeting at Madras.

The following is a statement of the financial position of the Society for the period beginning with 29th December, 1939 and ending with 30th November, 1940 :—

Income	Rs.	a.	p.	Expenditure	Rs.	a.	p.	Rs.	a.	p.
Previous balance	1,444	14	0	Printing of Journal				1,375	6	3
Admission fee	280	0	0	Remuneration for typing, etc.				50	0	0
Members' subscription	1,088	0	0	Postage at New Delhi				111	8	3
Subscriptions to the *Indian Journal of Entomology*	669	15	0	Branch Societies' expenses				22	0	0
Donation	100	0	0	Bank Commission				12	7	0
Cost of reprints	128	3	9	Stationery				48	11	0
Interest	10	1	0	Miscellaneous				48	9	0
Advertisements	57	0	0	Balance to the credit of the Society as under :—						
				Fixed Deposit in Bank	1000	0	0			
				Bank balance	952	5	6			
				Cheques in transit	55	0	0			
				Cash in hand	102	2	9	2,109	8	3
Total Rs.	3,778	1	9	Total Rs.				3,778	1	9

The Society's funds are deposited in the Imperial Bank of India, New Delhi, with Rs. 1000 in fixed-deposit and the rest in the current account.

The Society's accounts have been audited by Dr. Taskhir Ahmad, Assistant Entomologist, I.A.R.I., New Delhi, who was appointed for the purpose by the Executive Council. His remarks are as follows :—

"I certify that I have carefully examined the accounts of the Entomological Society of India for the year ending 30th November 1940. The Society started with a sum of Rs. 1,444/14/- brought forward from last year. During 1940 its net income from subscriptions both from members and for the Journal, donation, etc., was Rs. 2,333/3/9 and the expenditure incurred totalled Rs. 1,668/9/6. The net balance to the credit of the Society to date is Rs. 2,109/8/3, of which Rs. 2,007/5/6 is in the Imperial Bank of India and Rs. 102/2/9 with the Secretary. I have checked various sources of income and have scrutinised vouchers relating to different items of expenditure and find that the accounts have been kept in order. I have, however, to offer following remarks :—

(i) It is noticed that some mofassil members in remitting their annual subscription by cheque to the Secretary do not include bank commission, with the result that the amount actually received in the Society's account is short by -/4/- or so in many cases. Attention of members should be drawn to remedy this discrepency in future.

(ii) Certain sums of money are sent to or retained by Branch Societies for meeting their contingent expenses. These amounts should not be treated as expenditure but as advances which should be duly accounted for and balance, if any, should be shown to the credit of the Society when closing the accounts for the year."

Early in 1940, an application was made by the President to the Imperial Council of Agricultural Research for a grant-in-aid towards the publication of the *Indian Journal of Entomology*. I have pleasure in announcing that the Council has decided to give an annual grant of Rs. 500 for 3 years for this purpose.

The Society has now completed four years of its existence. Its achievements in 1940 are to be judged not so much by an increase in the number of its members and its income as by its increased internal strength which the war has seriously touched but not harmed. While the membership of the Society should still increase, of greater importance is the continued interest of the members who are already in the Society and the regularisation and establishing of the work and methods of proceedure of the Society, so that in years to come it may become a normally functioning unit and may be able to bear any strain, financial or otherwise, to which it may per chance be subjected.

DELHI BRANCH—NEW DELHI

29th January, 1941

General

Mr. Ramachandra Rao was elected President for 1941 and Mr. Mohan Singh Secretary for 1941-42 of the Branch Society.

The annual report of the Branch Society for 1940 was adopted. Dr. Lal gave a brief account of the Annual General Meeting of the Society held at Benares.

28th February, 1941

Exhibits

Aspidiotus destructor Sign., a pest of mango trees in Kashmir. First recorded in 1821 on coconut from Laccadives (India), this species is now known to be a serious pest of mango and palms. The other known host-plants are: *Cassia* sp., *Solanum melongena*, *Tamarindus indica*, *Carissa* sp., *Calotropis* sp., *Eugenia jambolana*, *Piper nigrum*, *Gelonium lanceolatum*, *Musa pardisiaca*, *Phoenix dactylifera* and *Ricinus communis*—V. P. RAO.

Sycanus collaris F., predaceous on larvæ of *Maruca testulalis*, boring into pods of *Cajanus cajan*, at Dehra Dun. Previously known to attack grubs of *Calopepla leayana* (Chrysomelidæ), *Hapalia machæralis* (Pyralidæ) and *Hyblaea puerá* (Noctuidæ)—M. BOSE.

Hemimerus deceptus var. *ovatus*, (Hemimeridæ : Dermaptera) collected at Morrogoro in Tanganyika, East Africa. Considered to be an ectoparasite of the farm rat, *Cricetomys gambiense*, but is probably a case akin to symbiosis. The species also feeds on the fungal spores growing on the body of the rodent and its excreta—P. J. DEORAS.

Chætocnema concinnipennis Baly, a pest of paddy seedlings—M. BOSE.

Communication

A note on the biology of *Chilomenes sexmaculata* Fab.—C. N. MODAWAL.

Discussion

On the rearing of mosquito larvæ—I. M. PURI.

16th March, 1941

General

Dr. T. V. Ramakrishna Ayyar, the President of the Society, gave a general address to the members of the Branch Society, on 'Insects and man.' He explained the important position insects occupy in the animal kingdom and the ignorance hitherto displayed by educated people regarding even common insects and their economic importance.

3rd May, 1941

Exhibit

Modified fly traps—ARJAN SINGH & P. J. DEORAS.

Communications

Two species of Embioptera from Delhi—RAMDAS MENON

New host-plants of some important insects—MOHAN SINGH

Some new Indian parasitic Hymenoptera—M. S. MANI

Notes on some Indian parasitic Hymenoptera—E. S. NARAYANAN

Studies on Indian Copeognatha (Psocoptera)—RAMDAS MENON

BENGAL BRANCH—CALCUTTA

9th December, 1940

Communication

Mr. R. Senior White, Malariologist, B. N. Ry. Co. Ltd., gave a lecture on "Malaria Vectorial capacity of mosquitoes as a test of species purity". Lively discussion followed and Mr. White answered various questions.

BIHAR BRANCH—PUSA

4th May, 1941

General.

Mr. L. N. Nigam, Sugarcane Entomologist, Bihar, was unanimously elected President for 1941 and Mr. A. C. Sen, Secretary for 1941-42.

The annual report of the Branch Society for the year 1940 was adopted and the President circulated to members the report on the main affairs of the Society for the period, January to April, 1941.

Resolution

Resolved that efforts should be made to enlist mofassil entomological workers particularly those stationed at Namkum (Ranchi) to become members and take part in the meetings of the Branch Society whenever possible.

Communication

Some observations on sugarcane pests in South Bihar—A. C. SEN.

THE PUNJAB BRANCH—LYALLPUR

14th December, 1940

Exhibit

Parasites of *ber* leaf caterpillar—K. N. TREHAN

Communication

Influence of stripping of sugarcane on the incidence of *Pyrilla*—PRATAP SINGH

20th January, 1941

Exhibit

Anapheis sp. as an alternative host of *Melcha nursei* Cameron. From pupæ of a butterfly, *Anapheis* sp. collected from *kareer* plant (*Capparis aphylla*) during October 1940, emerged in addition to some undetermined Chalcid parasites, two pairs of *Melcha nursei* during January to March, 1941. The caterpillar may, therefore, be regarded as a new alternative host of this parasite—K. N. TREHAN

25th February, 1941

General

Dr. Khan A. Rahman and Dr. S. A. Shah were unanimously elected as the President and the Secretary respectively of the Branch Society for the year 1941 and 1941-42.

Exhibit

Lasioderma serricorne F., a pest of tobacco and other stored products. Recorded doing serious damage to stored tobacco, turmeric, starch, stored *anabh* berries (*Zizyphus* sp.), etc. White eggs are laid singly in the folds, wrinkles, etc., of the tobacco leaves. They hatch in 9-14 days in April and May. The larvæ bore into the food, where they pass the entire larval and pupal stages. The adults are active creatures and may lay 30-94 eggs in 4-7 days.—GURCHARAN SINGH SOHI

Communication

Some field observations on *Scirpophaga nivella*—DALBIR SINGH

31st March, 1941

Exhibit

Pediculoides ventricosus Newport, a parasite of *Platyedra gossypiella*—A. N. SAPRA

Communication

On Brinjal borers, *Euzophera perticella* Reg. and *Leucinodes orbonalis* Guen.—S. A. SHAH

SOUTH INDIAN BRANCH—COIMBATORE

7th May, 1941

Communication

Preliminary studies on pollen-carrying capacity of the Indian bee—M. C. CHERIAN, S. RAMACHANDRAN & V. MAHADEVAN

A new species of *Trichospilus*, parasitic on pupæ of *Diatræa venosata*—V. MARGABANDHU & M. C. CHERIAN

Aporstocetus krishnieri Mani, a new internal parasite of amaranthus weevil *Lixus truncatulus*—P. N. KRISHNA AYYAR & M. C. CHERIAN

Exhibits

Two Sphingid moths, *Ambulyx pagana* bred from *Pongamia* leaves and *Choerocampa oldenlandiæ* from grape vine—T. V. SUBRAMANIAM

(1) Grubs of *Aubeus* sp. (Curculionidæ) infesting *Zizyphus jujuba* fruits at Panyam. The infestation takes place in the early blossom stage. (2) *Prodioctes hæmaticus*, the cardamom weevil from Korangumudi Estate in the Anamalais defoliating top shoots. In Ceylon, the grubs infest and destroy live rhizomes. (3) *Cryptothelia crameri* (West.) a bagworm infesting *Casuarina* shoots at Tindivanam. (4) *Nephopteryx eugraphella* (Pyralidæ) larvæ feeding on leaves and boring into fruits of sapota. (5) A new species of *Sphenuscomyia* fruitfly, the maggots of which breed in wild *Barleria* pods—M. C. CHERIAN

A large interesting paste-board nest of an ant (*Cremastogaster* sp.) collected from Yercaud Hills (3600 feet) in South India—P. N. KRISHNA AYYAR

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The Indian Journal of Entomology

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THE ENTOMOLOGICAL SOCIETY OF INDIA

Founded 1938

The Society exists for the encouragement and promotion of entomological study and research. It arranges for meetings of entomologists in different parts of the country and helps its members, specially those living in outlying districts, to keep in touch with entomological activities and workers, both in India and abroad. Membership of the Society is open to all persons over 18, interested in Entomology. Ordinary Members pay an admission fee of Rs. 10 and an annual subscription of Rs. 10. Students and others may join the Society as Associate Members and pay Rs. 5 as admission fee and Rs. 5 as annual subscription. The Society may also elect a small number of persons as Honorary Members, who are eminent for their services in the cause of Entomology. Owing to the difficulty of members from all over India meeting frequently at any one place, the Society has established branches at important scientific centres in different parts of the country, where its meetings are periodically held.

The Indian Journal of Entomology, which is the official publication of the Society, will for the present be published twice a year, in June and December, and will be supplied free to Ordinary and Honorary members. Associate Members will receive a copy of the general part of the Journal containing "Short Notes and Exhibits," "Recent Research," "Proceedings," etc. For non-members, institutions, departments, etc., the subscription is Rs. 15 per volume for supply in India and Rs. 16 in other countries.

Some limited space will be available for advertisements of entomological interest. Communications regarding advertisement and other business matters connected with the Society and the Journal should be addressed to the Joint Secretary, Entomological Society of India, Imperial Agricultural Research Institute, New Delhi.

EXECUTIVE COUNCIL FOR 1941

President	T. V. Ramakrishna Ayyar	Hyderabad (Deccan)
Vice-Presidents	M. Afzal Husain (*ex-President*)	Lahore
	Hem Singh Pruthi (*ex-President*)	New Delhi
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	Khan A. Rahman	Lyallpur
General Secretary	Taskhir Ahmad	New Delhi
Joint Secretary	S. Pradhan	New Delhi
Councillors	J. C. M. Gardner	Dehra Dun
	S. K. Sen	Mukteswar

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Punjab Branch	Khan A. Rahman	Lyallpur
Delhi ,,	Y. Ramachandra Rao	New Delhi
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Bengal ,,	D. D. Mukerji	Calcutta
South India ,,	M. C. Cherian	Coimbatore
United Provinces ,,	K. B. Lal	Cawnpore

The
Indian Journal of Entomology

Vol. III. Part 2 December 1941.

NOTES ON SOME PARASITES OF SHISHAM DEFOLIATORS AT ALLAHABAD AND DEHRA DUN, INDIA*

By P. N. CHATTERJEE, M.SC., D. PHIL. (Allahb.),

(*Formerly Empress Victoria Reader, Zoology Department, University of Allahabad*).

INTRODUCTION

During search for parasites of *shisham* (*Dalbergia sissoo*) pests made at Allahabad and Dehra Dun, thirty-three species of parasites were bred in the course of two seasons of 1938 and 1939; of these eleven are primary parasites of *Plecoptera reflexa* Guen., nine species are primary on *Dichomeris eridantis* Meyr., five are primary on *Leucoptera sphenograpta* Meyr., and two species are primary on *Cacœcia* sp.; six species are hyper-parasitic: three on *Plecoptera reflexa*, two on *Dichomeris eridantis* and one on *Cacœcia* sp. A complete list of species of parasites reared is being published separately, in which the economic status of each species is also discussed.

The information obtained on the biology of 19 species of parasites is presented in the following pages. Some of the parasites are still to be specifically named, identifications of which have been delayed on account of the existing conditions of war.

The species of parasites have been arranged in systematic order, with their hosts and distribution; other locality data, besides Allahabad and Dehra Dun, have been reproduced from the *Indian Forest Records*.

* When sending this paper to press, Dr. N. C. Chatterjee drew my attention to a paper by R. N., Mathur, 1941, *Indian For. Rec., Ent.*, (in press) on the biology of the parasites of the *shisham* defoliators in the Punjab with a note by C. F. C. Beeson, which gives a detailed ecological account.

HYMENOPTERA

BRACONIDAE

Apanteles sp.

Host.—*Plecoptera reflexa* Guen. (Noctuidæ).

Distribution.—United Provinces—Dehra Dun.

Parasitism experiments.—It is a solitary endoparasite. Laboratory-bred host larvæ of the second stage are parasitised. The host larva slightly turns pink when the parasitic larva reaches its last stage inside the host. Before the last stage parasite larva bores out, the host larva develops a small black spot from which point parasite comes out. When the larva thus bores out of the host, the latter is still able to move, but dies within 24 hours.

Full-grown larva.—Measures 5.0 x 1.5 mm., white in colour, 11 body segments, armed with setæ; contents of alimentary canal green; a pair of complexly coiled salivary glands on either side of alimentary canal. Head 0.34 mm. wide, with unsegmented antennæ, bounded by chitinised bars of maxillary and labial scleromes and hypostoma; hypostoma 0.11 mm. long; labium 0.13 x 0.1 mm., enclosing setæ and palpi; mandible 0.2 x 0.6 mm., chitinised, tip bifurcated, blade with 9 teeth (Figs. 1-4).

Cocoon.—As soon as the larva bores out of the host it starts spinning a barrel-shaped white cocoon, covered with loose silk threads outside, giving it an appearance of teased cotton. The "male cocoon" measures 3.9 x 1.4 mm. and the "female cocoon" measures 3.9 x 1.8 mm. The adult emerges from the cocoon by cutting off the usual circular cap-like lid.

The cocoons of *Apanteles* sp. and *Microgaster plecopteræ* are very similar in appearance, except that the former looks like teased cotton and is a little smaller in size.

Life-cycle.—The incubation and larval periods last together 7 days and cocoon period 4 days, making a total of 11 days in April.

Apanteles sp. (B 7)

Host.—*Dichomeris eridantis* Meyr. (Gelechiidæ).

Distribution.—United Provinces—Allahabad and Dehra Dun; Punjab.

It is a solitary endoparasite. The full-grown larva bores out of the host and forms its cocoon outside, within the leaf folded by the host caterpillar. The length of the cocoon period at Dehra Dun is 6 days in June and at Allahabad 6 to 7 days in March and 7 days in April.

This Braconid is itself parasitised by *Mesochorus* sp. (Ichneumonidæ) and *Brachymeria* sp. (Chalcididæ); the former was bred at Allahabad in

April and the latter in March and May 1939 at Allahabad and Dehra Dun respectively. *Mesochorus* emerges on about the tenth day from the date of cocoon-formation and escapes by making an irregular hole on the surface of the cocoon.

Apanteles sp. (A)

Host.—*Cacœcia* sp. (Tortricidæ).

Distribution.—United Provinces—Allahabad.

It is a solitary endoparasite. At Allahabad it formed 44.4% and 23.5% of the total of parasitised caterpillars in 1938 and 1939 respectively. The cocoon period varied from 9 to 10 days in March-April.

Camptothlipsis furtifica Wilkinson

Host.—*Dichomeris eridantis* Meyr. (Gelechiidæ).

Distribution.—United Provinces—Allahabad, Dehra Dun; Punjab—Multan, Chichawatni, Montgomery, Khanewal; North-West Frontier Province.

It is a solitary endoparasite. It forms cocoon outside the host larva. The cocoon period is 7 to 10 days at Allahabad in March and April and 5 days in May at Dehra Dun.

The cocoon is white with a few scattered silk hairs, barrel-shaped and found inside the fold of *shisham* leaf. The adult emerges by cutting an irregular hole at the head end of cocoon.

The "male cocoon" measures 6 x 2 mm. and the "female cocoon" measures 7 x 3 mm.

Disophrys sissoo Wilkinson

Host.—*Plecoptera reflexa* Guen. (Noctuidæ).

Distribution.—United Provinces—Allahabad, Dehra Dun; Punjab—Montgomery, Changa Manga, Chichawatni.

Parasitism experiments.—It is a solitary endoparasite. Nine second stage caterpillars were exposed to the parasites. Four cocoons were formed on 24th May 1939, *i.e.*, on the eighth day from the time of introduction; males emerged on 31st May; 1 larva dissected on the second day of introduction yielded one egg in the developing stage; and one caterpillar yielded a living larva; the remaining larvæ escaped parasitisation.

Thus it will be seen that 66.6% parasitism was obtained.

Life-cycle.—at Dehra Dun during May is 15 days : incubation period 2 days, larval period 6 days and cocoon period 7 days.

Immature stages.—Four days old larva measures 1.1 x 0.14 mm., with 13 body segments, the last being blunt ; on segments 6, 7, 8, 9, 10 and 11 blunt tubercles project downwards from sides ; no anal vesicle ; 6 spiracular centres. Head 0.3 x 0.2 mm., rectangular ; mandible 0.7 mm. long, chitinised, hooked (Fig. 5).

Intermediate stage larva measures 3.41 x 0.6 mm., 9 pairs of spiracles. Head not distinct ; mandible 0.1 x 0.3 mm., less sclerotized, blade with traces of dentition.

Full-grown larva measures 6 x 2 mm., 13 body segments, armed with setæ ; 9 pairs of spiracles, situated on T^*_2, T_3 and A^*_2-A_8 ; spiracle T_2, T_3 about twice the size of A. Head 0.9 x 0.5 mm., prominent and retractile, with unsegmented antennæ ; mandible 0.12 x 0.15 mm., chitinised, blade carries 18 saw-like teeth (Figs. 6, 7).

Cocoon.—The full-grown larva bores out of the third stage host larva. It spins a white barrel-shaped cocoon. The male cocoon measures 8.5 x 3.5 mm. and the female cocoon 10 x 4 mm. The adult parasite emerges by a circular cap, cut in a slanting manner.

Microgaster plecopteræ Wilkinson

Host.—*Plecoptera reflexa* Guen. (Noctuidæ).

Distribution.—United Provinces—Dehra Dun ; Punjab—Montgomery, Changa Manga, Chichawatni, Multan and Khanewal.

It is a solitary endoparasite. Notes on the biology of the species have been given by Beeson and Chatterjee (1935).

Parasitism experiments.—The second-stage host larvæ are parasitised; older stages are not approached and the first stage larva is not suitable ; a similar observation was made with *Apanteles machæralis* by Chatterjee (1939). Sixty second-stage larvæ in batches of 6, 6, 12, 12, 12, and 12 were released for parasitisation by two females which emerged on two different dates from the field-collected cocoons :—14 larvæ were parasitised, from which (a) 11 cocoons were formed, (b) 3 dead larvæ on dissection yielded three dead grubs of the parasite, and (c) the rest of the larvæ were not parasitised. Thus it will be seen that only 23.3 % parasitism was obtained.

* T and A denote thoracic and abdominal segments ; lower digits denote the segment number.

Life-cycle.—It takes 16 to 19 days for the parasite to develop from egg to adult, between May and July :

	May	June	July(part)	October
Incubation+larval period in days =	10	9	9	—
Cocoon period in days =	6	8-10	9	8
Total period up to the emergence of adult =	16	17-19	18	—

Immature stages.—Egg measures 0.33 x 0.1 mm., white in colour, cylindrical ; mature egg opaque, practically filled with mitochondrial yolk bodies. (Fig. 11).

First larva is white, shows peristaltic movement when freshly dissected ; 12 body segments ; alimentary canal straight, with pale green contents ; anal vesicle 0.63 x 0.3 mm., spiracles not seen. Head 0.2 x 0.11 mm., not sclerotized, bounded by maxillary sclerome ; mandible 0.1 mm. long, less chitinised, pointed, edentate. (Figs. 12, 13).

Full-grown larva measures 7.03 x 1.7 mm., dirty white ; anal vesicle not seen ; 9 pairs of spiracles ; body armed with setæ. Head 0.2 x 0.4 mm., sclerotized, bounded by labial and maxillary scleromes and hypostoma. Labial sclerome horse-shoe shaped, enclosing labium ; labium 0.13 x 0.13 mm., containing labial palpi and setæ ; opening of silk duct in the gap of horse-shoe-shaped labial sclerome ; arms of labial sclerome join hypostoma, the ends of which mark the boundary of head. Maxillary sclerome 0.2 mm. long, encloses a pair of maxillary palpi and setæ. Mandible 0.13 x 0.03 mm., tip bifurcated, edentate. (Figs. 14, 15).

The full-grown larva bores out of the third stage host larva, leaving behind its last moult at the entrance of the hole, marked by a black ring. In a few hours it spins a tough, white, barrel-shaped cocoon. The 'female cocoon' measures 4.5 x 2 mm. and the 'male cocoon' measures 4 x 1.5 mm. The outer surface of the cocoon is evenly covered by fine silk threads.

Microbracon sp. (2)*

Host.—Dichomeris eridantis Meyr. (Gelechiidæ).

Distribution.—United Provinces—Allahabad.

This species is a gregarious ectoparasite bred at Allahabad in March 1939. The female is light orange in colour with abdomen slightly bent downwards ; the contents of the abdomen are green ; thorax is brownish-red.

* According to S. N. Chatterjee, it is a species of *Avga*, possibly *choaspes* Nixon.
"Indian J. Ent., **3** (2)"

In the laboratory a female parasite laid two eggs on the dorsal side of *Dichomeris* larva of an early stage; the larva quickly feeds on the host. In the act of oviposition the female inserts her ovipositor into the leaf fold, inside which the young larva lives.

Full-grown larva measures 1.8 x 0.8 mm., cylindrical; 12 body segments, anterior segment slightly broader than posterior, humped appearance on A_1-A_7; armed with setæ. Head 0.23 mm. wide, armed with setæ.

Life-cycle.—The life-cycle in March occupies 9 days; the incubation and larval period is 4 days and cocoon period 5 days.

Cocoon.—The cocoon is flat and three-sided; it is white and transparent. The parasite emerges from the cocoon by making a slightly elongated hole. The cocoon measures 4 x 1 mm.

Meteorus dichomeridis Wilkinson

Host.—*Dichomeris eridantis* Meyr. (Gelechiidæ).

Distribution.—United Provinces—Allahabad and Dehra Dun; Punjab—Montgomery, Chichawatni and Khanewal; N. W. F. P.

It is a solitary endoparasite. The larva bores out of the third stage larva and forms its cocoon outside near the head of the dead host. The cocoon period is 6 to 7 days in May and June at Dehra Dun.

Cocoon.—The cocoon is light pink and barrel-shaped; the posterior end is slightly rounded and the anterior end is cone-shaped. The cocoon is formed inside the *Dichomeris* fold of *shisham* containing larva.

The 'male cocoon' measures 4 x 2 mm. and the 'female cocoon' 5 x 2 mm.

BETHYLIDAE

Bethylus distigma Motschulsky*

Host.—*Cacœcia* sp. (Tortricidæ).

Distribution.—United Provinces—Allahabad.

Parasitism experiments.—It is a gregarious ectoparasite. The paralysed host larva becomes motionless, turns whitish-yellow and though able to move can not escape. From the time the eggs are laid, the mother keeps guard till her progeny is out. She lays a maximum of six eggs in series on the lateral segments of one host larva. The female when forcibly removed from her progeny and kept with another host, sometimes paralyses and lays eggs on it;

* *Goniozus montanus* Kieff. of previous authors is a synonym of *Bethylus distigma* Motsch. vide Kieffer, *Das Tierreich*, **41**: 514, (1914). I am indebted to Mr. M. S. Mani, New Delhi, for synonymy of this species.

ordinarily one female paralyses one host only and feeds on the exudation. Similar observation has been made by Beeson and Chatterjee with *Cedria paradoxa* (1935) and Clausen (1940).

In the field the parasite was collected in all different stages—egg, larva, cocoon and adult—inside the leaf-fold of *Cacœcia* sp. on *shisham.*

Immature stages.—Egg measures 0.6 x 0.1 mm., white and opaque, cylindrical. First stage larva measures 1.3 x 0.4 mm., cylindrical, colourless and opaque, tracheal system well developed. Full-grown larva measures 3 x 1.1 mm., cylindrical, armed with setæ; 12 body segments, contents of mesenteron brownish-yellow; 10 pairs of spiracles, those of T_2, T_3 twice the size of A_2-A_9. Head 0.3 mm. wide, bounded by maxillary and labial scleromes and hypostoma; mandible 0.04 x 0.11 mm., chitinised, yellow, tip pointed, edentate.

Cocoon.—The full-grown larva spins white, thin silken cocoons in clusters of six inside the fold of the *shisham* leaf. The cocoon is barrel-shaped and measures 3.3 x 1.48 mm. The parasite emerges by cutting an irregular hole on the dorsal side, a little behind the anterior end of the cocoon; it leaves no cap.

Life-cycle.—The life-cycle from the time of egg-laying to the emergence of adult is 11 days in March at Allahabad as below: the incubation period is one day, larval period 3 days and cocoon period 7 days.

Hyperparasites.—One species of Chalcid has been bred from the field-collected cocoons of *B. distigma* at Allahabad in March-April.

ICHNEUMONIDAE

Henicospilus sp. (B)

Host.—Plecoptera reflexa Guen. (Noctuidæ).

Distribution.—United Provinces—Allahabad and Dehra Dun.

It is a solitary endoparasite.

Full-grown larva measures 16 x 4 mm., is robust-looking and heavy, ash-coloured; alimentary canal dirty ash; 13 body segments, armed with spines. Head 1 x 0.6 mm., bounded by maxillary and labial scleromes; mandible 0.2 x 0.1 mm., chitinised, edentate with comb-like serrated margin. (Figs. 9-10).

Cocoon.—The full-grown larva of the parasite wriggles about inside the cage in search of some support for the purpose of spinning its cocoon. It takes about one day to complete cocoon formation.

The cocoon is long, barrel-shaped and chocolate-brown; the outer surface slightly hairy in appearance. The "female cocoon" measures

10 x 4.9 mm. The adult emerges from the cocoon by cutting a circular cap which remains hinged to the cocoon.

The mandible of the adult female measures 0.1 x 0.1 mm.; it is heavily chitinised, yellow, pointed and edentate.

CHALCIDIDAE

Brachymeria nephantidis Gahan

Hosts.—*Dichomeris eridantis* Meyr. (Gelechiidæ) a new record; also other hosts (Beeson and Chatterjee, 1939).

Distribution.—United Provinces—Allahabad and Dehra Dun; Madras—Nilambur, Mangalore, Samalkotah, Godavari and Coimbatore.

It is a solitary internal pupal parasite. It is an important parasite on account of its polyphagous nature (Beeson and Chatterjee, 1939). The adult emerges from the host pupa by making an irregular opening on its body. It was bred in September 1938 at Allahabad.

ENCYRTIDAE

Paralitomastix varicornis (Nees)

Host.—*Dichomeris eridantis* Meyr. (Gelechiidae)

Distribution.—United Provinces—Allahabad and Dehra Dun and Saharanpur; Punjab; Sind; Europe.

It is a polyembryonic species, bred from larva of *Dichomeris eridantis*; as these Encyrtids reach the pupal stage inside the host larva, the host becomes stiff and straight or curled; it looks black from outside on account of the black pupæ of the Encyrtids; the adult Encyrtids emerge in about 8 to 9 days from the time the host is observed to become straight and stiff; the parasites emerge by making small holes on the body of the larva; from one host 125 and 75 Encyrtids have emerged; but a maximum of 265 is also recorded from one host.

Paralitomastix sp.

Host.—*Dichomeris eridantis* Meyr. (Gelechiidæ)

Distribution.—United Provinces—Allahabad.

This parasite is provisionally placed under the above genus; it is a polyembryonic species; 78 Encyrtids have emerged from a single larva; the parasitised host larvæ become stiff and straight.

ELASMIDAE

Elasmus sp.

Host.—Leucoptera sphenograpta Meyr. (Lyonetiadæ).

Distribution.—United Provinces—Allahabad.

It is a solitary endoparasite, bred from the pupa of *Leucoptera sphenograpta* in February and March 1938 and March 1939. It represented 47% and 18% of the total parasitism in 1938 and 1939 respectively. The female parasite inserts her ovipositor through the mined leaf of *shisham* and after some repeated attempts, parasitises the larva. From such a parasitised larva the adult parasite emerged on the 14th day (*i.e.*, from the time of parasitisation to the time of emergence of adult parasite).

DIPTERA

TACHINIDAE

Cadurcia vanderwulpi Baranoff

Hosts.—Dichomeris eridantis Meyr. (Gelechiidæ) ; also other hosts (Beeson and Chatterjee 1939).

Distribution.—United Provinces—Allahabad, Dehra Dun, Haldwani, Chakrata ; Punjab—Lahore, Montgomery, Multan ; Sind—Shikarpur.

This solitary endoparasite has been previously recorded as *zetterstedti* v.d. Wulp by Beeson and Chatterjee (1935). It is a new record for *Dichomeris* and was bred at Allahabad in March 1938 and in the Punjab and Sind in April-September.

The fly passes its early stages inside the host larva and the last stage within the host pupa ; the maggot comes out of the pupa and forms the puparium outside. The approximate larval period of *Cadurcia* passed inside the host larva is 5 days ; the number of days passed inside the host pupa is approximately 7 to 10 days and pupal period of the parasite passed inside the puparium is 7 days ; thus the approximate total life period in March is 17 days.

The puparium, described by Gardner (1940), is 4 mm. long ; the fly emerges from the puparium on the seventh day. It represented 28.5% of the total parasitism in March 1938.

Carcelia (Sysyropa) thermophila Wilcox

Host.—Plecoptera reflexa Guen. (Noctuidæ).

Distribution.— United Provinces—Allahabad.

A new record as a parasite of *Plecoptera reflexa*, it formed 16.6% of the total parasitism in September. The puparium is described by Gardner (1940).

Exorista picta Baranoff

Host.—Plecoptera reflexa Guen. (Noctuidæ).

Distribution.—United Provinces—Allahabad and Dehra Dun; Punjab—Montgomery, Chichawatni.

It is a solitary endoparasite. The maggot passes 11 to 15 days inside the host larva and 3 to 4 days inside the host pupa, after which it forms a puparium outside. The puparium is described by Gardner (1940). The pupal period is 8 to 10 days, after which the adult fly emerges; it takes a couple of hours for the fly to become active.

The approximate life-cycle at Allahabad in February and March is 20 to 22 days; incubation and larval periods 12 days and pupal period 8 to 10 days.

The pupal period at Dehra Dun in September-October is 9 days.

Eutachina civiloides Baranoff

Hosts.—Plecoptera reflexa Guen. (Noctuidæ); also other hosts (Beeson and Chatterjee, 1939).

Distribution.—United Provinces—Dehra Dun and Haldwani; Punjab—Lahore, Montgomery and Multan; Madras—Nilambur; N. W. F. P.—Lower Swat Canal; Burma.

It is a solitary endoparasite. This fly was found to be a parasite of *Plecoptera reflexa* at Dehra Dun in May 1939. It represented 1.8% of the total parasitism. The puparial period is 7 days in May at Dehra Dun. The puparium is described by Gardner (1940).

Podomyia setosa Dol

Host.—Plecoptera reflexa Guen. (Noctuidæ).

Distribution.—United Provinces—Allahabad and Dehra Dun; Punjab—Montgomery and Chichawatni.

It is a solitary endoparasite. Beeson and Chatterjee (1935) published notes on the biology of the species.

Parasitism experiments.—Third and later stages of the host larvæ are able to support the maggots of *Podomyia*. The host larvæ swallow the eggs while eating leaves*; the larva may swallow more than one egg inadvertently, if more than one egg is found on the leaf.

*Egg-free field-collected *shisham* leaves were used for parasitism experiment.

The parasitism experiment was carried out in mass method, exposing laboratory-bred and field-collected larvæ. Forty-seven larvæ of third and fourth stages bred in the laboratory were exposed to 130 eggs of *Podomyia setosa* between 20th September and 8th October 1938, at Dehra Dun :—

(i) 17 host larvæ were parasitised, of which 7 formed puparia between the 10th and 13th days from the date of introduction ;

(ii) 1 host pupated on the 9th day ; on dissection it yielded 3 dead maggots and 1 living maggot of the first stage ;

(iii) 1 host larva dissected on the 7th day and it yielded 1 first stage maggot enclosed inside a sheath ;

(iv) 1 dead host pupa dissected on the 13th day and it yielded 6 dead maggots ;

(v) 6 host larvæ were dissected in the dying state on the 10th day and yielded 4, 6, 3, 7, 2 and 2 maggots respectively;

(vi) 1 prepupal host larva dissected on the 9th day and it yielded 15 living maggots ;

(vii) 30 host larvæ were unparasitised.

Total 47

Eight larvæ of third stage collected in the field were exposed to 8 eggs of *Podomyia setosa* on September 28 ; the results are summarised below :—

(i) 1 host yielded one cocoon of *Microgaster plecopteræ* on 3rd October ; the dead host on dissection yielded 1 living maggot of the fly ;

(ii) 1 host yielded 1 dead maggot of *Microgaster plecopteræ* and 1 dead maggot of fly on dissection on 6th October;

(iii) 2 host larvæ yielded 2 *Microgaster plecopteræ* cocoons on 3rd October ; the dead host on dissection yielded no maggots of the fly *Podomyia* ;

(iv) 4 host larvæ pupated normally.

It will be seen that 36.17% of the laboratory-bred host were parasitised ; 54.8% of *Podomyia* eggs were swallowed by 17 host larvæ and 45.2% of the eggs were wasted.

Life-cycle.—The life-cycle of *Podomyia setosa* is completed between 18 and 21 days in the month of October at Dehra Dun ; incubation period from the time the egg is swallowed by host larva is 2 days, larval period 8 to 9 days and pupal period 8 to 10 days.

Superparasitism and multiparasitism.—Cases of super- and multiparasitisms have been observed in the experiments carried out with the laboratory-bred and field-collected larvæ ; in the former case as many as 15 maggots were infesting one host larva, of which three maggots were living inside the head capsule ; the effect of superparasitism is death of both the host and parasite. In the latter case, larvæ and cocoons of *Microgaster plecopteræ* were obtained along with the maggots of *Podomyia setosa.* The effect of multiparasitism is usually the death of three species, but in one case *Microgaster plecopteræ* survived.

External signs of parasitism.—It is only in the host pupa that the external signs of parasitism can be observed. The last three abdominal

segments of a normal host pupa are moveable but in the parasitised pupa these segments do not move. Further, a normal host pupa, till the emergence of imago is opaque ; but the parasitised pupa is opaque in the middle and lighter at the anterior and posterior extremities.

Oviposition.—The fly rubs the tip of its abdomen on the edge of green leaves and thus fixing the eggs to the hairs of leaf.

Immature stages.—Egg measures 0.2 x 0.1 mm., pear-shaped, black, shining and hard (Fig. 16). The three days old maggot measures 1.52 x 0.52 mm., is colourless, enclosed in a membranous sheath and embeded in the tissue of the host, shows rhythmical movements in living state ; contents of alimentary canal green ; malpighian tubes present ; posterior pair of spiracle brown, situated on A_9. Head with few shagreen spinules ; cephalopharyngeal skeleton 0.9 mm., long, composed of a hooked mandibular sclerite, brown. (Fig. 17). The seven days old maggot measures 3.7 x 1.3 mm., each segment beset with shagreen spinules ; posterior spiracle black ; cephalopharyngeal skeleton composed of mandibular sclerite (0.4 x 0.1 mm.), hypostomal and pharyngeal sclerite (0.3 x 0.2 mm.). (Fig. 18). Full-grown or the twelve days old maggot measures 17 x 9 mm., uniform pigmented skin, 13 body segments, 3 rows of shagreen spinules on each segment ; posterior spiracle jet-black, protruding anterior spiracle brown, withdrawn in pocket ; alimentary canal greatly lengthened and coiled ; oesophagus prolonged backwards ; numerous malpighian tubes ; muscular system well developed. Cephalopharyngeal skeleton composed of mandibular hypostomal and pharyngeal sclerites ; mandibular sclerite bifurcated at tip, articulates basally with hypostomal, the halves of the latter joined by a transverse bar ; mandibular and hypostomal sclerite 0.4 x 0.1 mm. ; pharyngeal sclerite 0.6 x 0.3 mm., formed of two lateral and vertical lamellæ, uniting ventrally to form a trough (Fig. 19).

Gardner (1940) has described the puparium. The 'female' puparium measures 7 x 3.8 mm., and the 'male' 6.5 x 3.5 mm. The fly emerges from the puparium by an annular dehiscence at the anterior end pushing off a cap.

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SUMMARY

Hosts	PARASITES							
	LARVAL							PUPAL
	Solitary internal				Gregarious internal		Polyembryonic	Solitary internal
	Braconidæ	Ichneumonidæ	Elasmidæ	Tachinidæ	Braconidæ	Bethylidæ	Encyrtidæ	Chalcididæ
Plecoptera reflexa	*Apanteles* sp. *Disophrys sissoo*	*Henicospilus* sp. (B.)		*Carcelia (Sysyropa) thermophila* *Exorista picta* *Eutachina civiloides* *Podomyia setosa*			*Paralitomastix varicornis* *Paralitomastix* sp.	
Dichomeris eridantis	*Apanteles* sp. (B. 7) *Camptothlipsis furtifica* *Meteorus dichomeridis*			*Cadurcia vanderwulpi*	*Microbracon* sp. 2			*Brachymeria nephantidis*
Leucoptera sphenograpta			*Elasmus* sp.					
Cacœcia sp.	*Apanteles* sp. (A.)					*Bethylus distigma*		

of literature; the author is indebted for constant advice, identifications and valuable suggestions to Mr. J. C. M. Gardner, I.F.S., Forest Entomologist and Mr. S. N. Chatterjee, F.R.E.S., Branch of Forest Entomology and finally the author is grateful to the President, Forest Research Institute, Dehra Dun, for permission to work as a research student in the laboratories of the Forest Entomologist. The award of the Empress Victoria Readership by the University of Allahabad is gratefully acknowledged.

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KEY TO LETTERING OF FIGURES 1—19

A. antennæ; Ac. alimentary canal; Av. anal vesicle; Csk. cephalopharyngeal skeleton; H. head; Hs. hypostomal sclerite; Ls. Labial sclerome; Lp. labial palpi; Lst. labial setæ; L. labium; M. mandible; Mp. maxillary palp. Ms. maxillary setæ; Msl. maxillary sclerome; Mt. mouth; M 1, 2, 3, L. larvæ of 1st, 2nd, 3rd and last stage; Md 1, 2, 3, L. mandible of 1st, 2nd, 3rd and last stage larvæ; Mts. malpighian tubules; Mds. mandibular sclerite; Psc. pharyngeal sclerite; S. salivary glands; Sp. spines; Sdo. silk duct opening; Spl. spiracle; Sgs. shagreen spinules; T. trachea; Tr. tracheole; Tt. tail like thread.

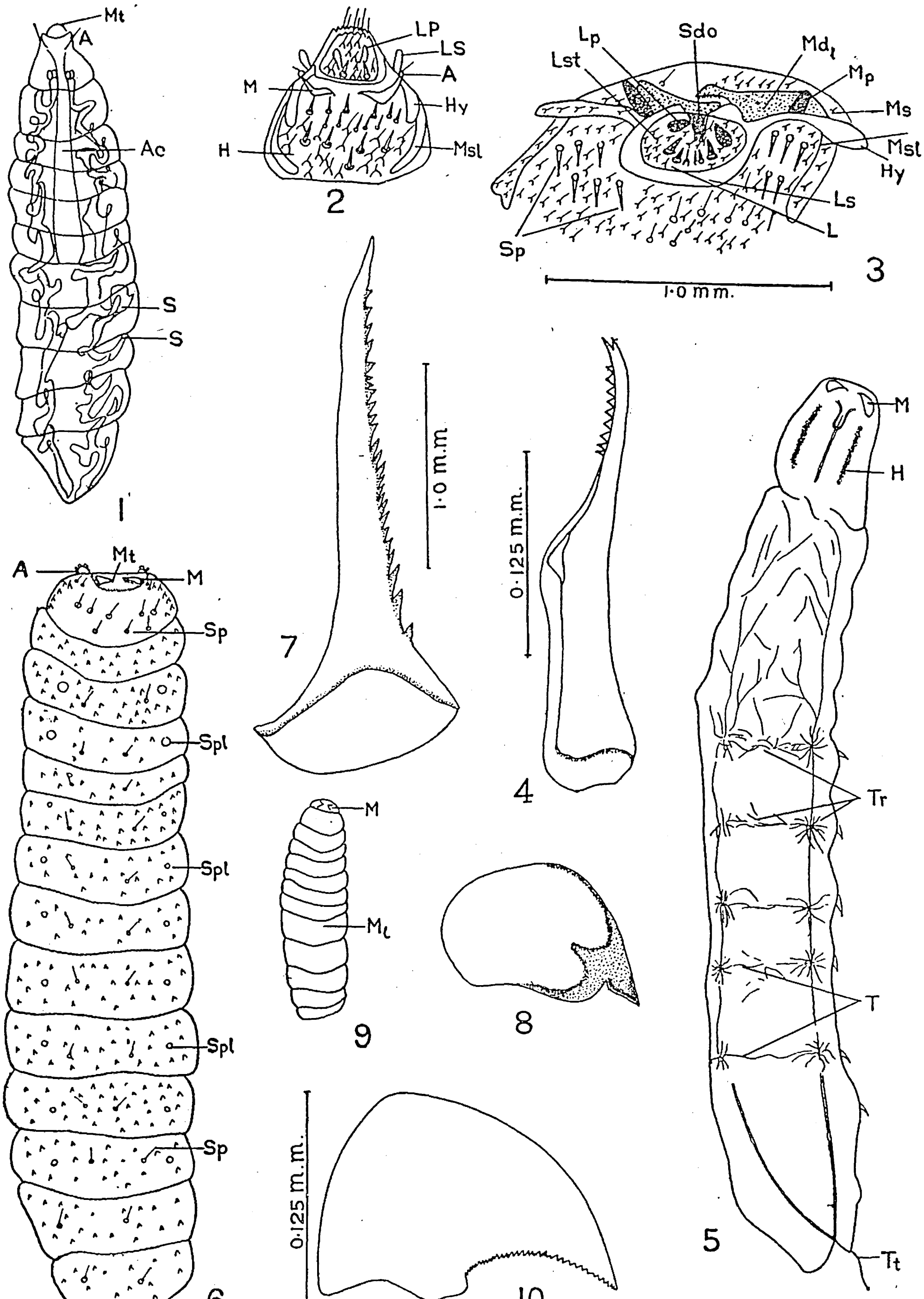
Figs. 1—4. *Apanteles sp*; 1. Full-grown larva (diagrammatic) x14; 2. Head of the full-grown larva; 3. Head structure of the same; 4. Mandible of the same.

Figs. 5—8. *Disophrya sissoo*; 5. First stage larva; 6. Full-grown larva (diagrammatic) x21; 7. Mandible of full-grown larva; 8. Mandible of the adult female.

Figs. 9—10. *Henicospilus sp. (B.)* 9. Full-grown larva (diagrammatic) x3; 10. Mandible of the full-grown larva.

Figs. 11—15. *Microgaster plecopteræ*; 11. Egg; 12. First stage larva; 13. Head of the first stage larva; 14. Full-grown larva (in part, showing anterior end); 15. Mandible of the same.

Figs. 16—19. *Podomyia setosa*; 16. Egg; 17. First stage maggot; 18. 7th day maggot (showing in part anterior and posterior ends); 19. Cephalopharyngeal skeleton of 12th day maggot (last stage).



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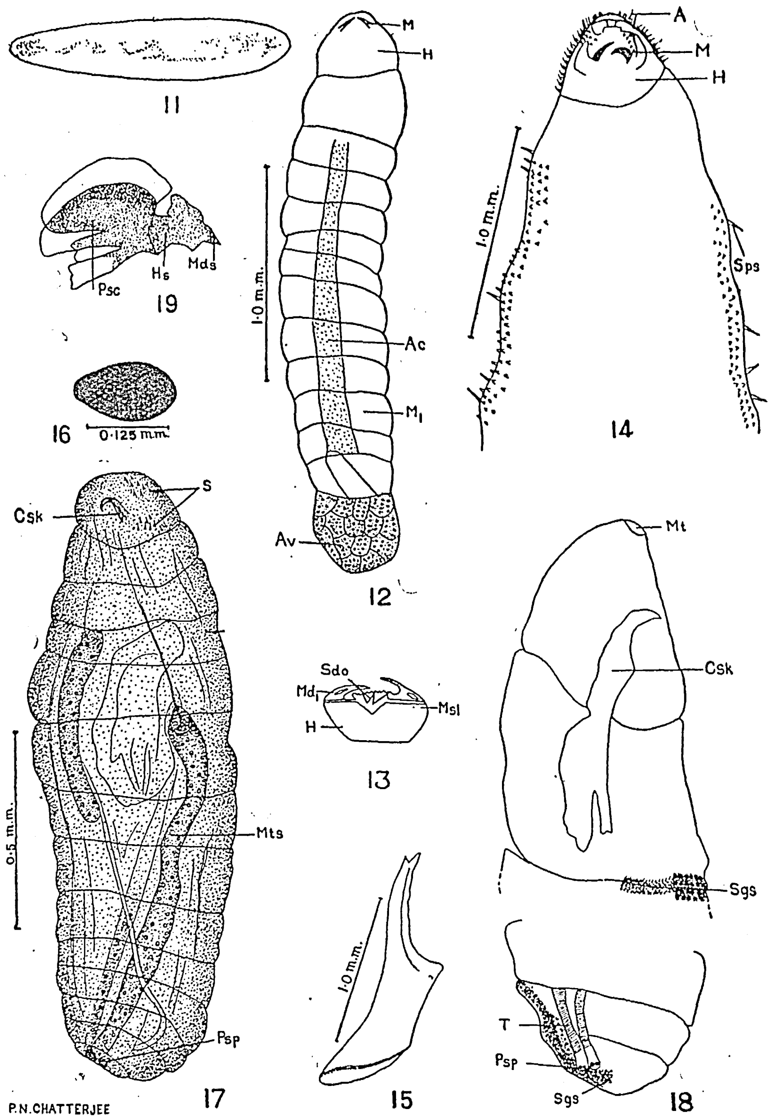
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RHACONOTUS ROSLINENSIS (BRACONIDÆ), A LARVAL PARASITE OF THE SUGARCANE BORER, *SCIRPOPHAGA RHODOPROCTALIS*

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Introduction

During the course of a study of the natural enemies of the sugarcane white moth-borer, seven larval parasites were noted : the results of the studies on four of these, *viz.*, *Elasmus zehntneri* Ferr., *Stenobracon nicevillei* (Bingh.), *Rhaconotus scirpophagæ* Wlkn., and *Stenobracon deesæ* (Cam.) have already been published by the authors (1937 and 1938). The present paper gives some information on the habits and life-history of *Rhaconotus roslinensis* Lal. *R. caulicola*, described by Muesebeck (1940), is identical with this species.

Host and its habits

A brief account of the nature of the damage caused by the moth-borer along with its life-history and habit is necessary, so that the activities of the parasite can be better understood. The moth-borer is a fairly serious pest of young as well as full-grown canes. The characteristic buff-coloured egg mass is laid by the moth, generally on the under-surface of sugarcane leaves. The larvæ on hatching find their way into the leaf-roll and destroy the young growing-point by tunnelling downwards and eating through the soft tissues of the cane. Only one larva is found in each plant. When full-fed, it excavates a short tunnel and closes its external opening with a lid constructed from the outermost leaf-sheath. It then withdraws itself into the tunnel, spinning partitions of silk one behind the other and finally pupates. The moth in due course emerges through the exit hole. The total life-cycle of the pest is about 2 to 2½ months.

Habits of the parasite

Oviposition.—The parasites do not oviposit until 3-5 days after emergence. The first indication of the female becoming ready for oviposition is the slight unsheathing of the ovipositor. When a stem with

the host larva inside is supplied, the parasite commences to feel the position of the larva inside with its extended antennæ. When once it locates the host, it raises the abdomen and brings its ovipositor to a point under the body, while the sheath describes a loop and thrusts the ovipositor through the lid to reach the host larva. With a single thrust of the ovipositor the parasite may or may not reach the host larva. It does not abandon the spot till it encounters the larva and paralyses it. With a short ovipositor, measuring 0.5 mm., it is not easy for the parasite to get at the host unless it carefully watches and waits for the time when the latter comes to cut the outermost lid. This would explain the length of time, 30 to 60 minutes, taken by it to get at the host. Eggs are laid, only after the host is paralysed, in clusters of 3 to 33 on or near the head of the host. The parasites are mostly active in the morning. In the laboratory, a female lays on an average 26 eggs ranging from 8 to 47 on one or more hosts. In its habits, it is more like *Rhaconotus scirpophagæ* and never scatters its eggs on many hosts. It deposits its eggs in batches at irregular intervals, depending upon the maturity of the eggs inside. Ordinarily, the parasite does not attack a host, on which eggs have already been laid but when a single host larva was subjected in the laboratory to the activities of a number of parasites, more than one parasite laid eggs simultaneously. When one or more hosts are supplied, the parasite laid its eggs only on one. It also does not accept a host which is not inside the tunnel.

Longevity.—The maximum duration of life under laboratory conditions, when fed with honey solution, was found to be 47 days for females and 43 days for males, the average for 13 females being 21 days and for 7 males 32 days. Without food no parasite lived for more than 8 days.

Emergence.—When the adult parasite is ready to emerge, it cuts a small hole through the cocoons and crawls out of it. But it finds its emergence to the outside world further obstructed by the lid constructed by the host. The parasite then cuts a hole in this lid and escapes.

Proportion of sexes

Out of 308 adults which emerged from 20 cocoon spindles, the number of females was 264, their percentage being 85. In rearings in the laboratory also the proportion of females to the males was about the same. The preponderance of females does not appear to be affected by seasonal changes; it prevails in much the same degree both in the dry and wet months.

Parasite production from a single host

On an average about 15 adults emerged from each host larva collected

from the field, the maximum and minimum being 25 and 6 respectively.

Life-history

Eggs are generally transluscent, about 1.0 mm. long, elongate, cylindrical, curved in the middle, with one end more pointed than the other. Eggs are laid in clusters attached to the inner circumference of the tunnel or, in some cases, on the head of the host. The period of hatching depends upon the conditions of the weather. During summer it is 24-26 hours, while it is double this period in cold weather.

The newly-hatched grub measures 0.5 mm., is colourless and transparent on hatching, gradually attaining the colour of the host as it begins to feed on it. If the eggs are not laid on the body of the host, the parasites wander about on the smooth silken lining of the larval tunnel until they reach the host. The grubs attach themselves firmly to the body of the host and puncture it at some tender part of the cuticle and suck the food material. These punctures with black circular demarcations are clearly seen on the body of the host. The grubs do not thrive on unparalysed or artificially killed host larvæ. They actively feed on the host for 3-6 days and reach their maximum size of 4.0 mm. x 1.5 mm., by which time the host larva is completely eviscerated. The grubs then spin cigar-shaped, white silken cocoons which measure 5.0 to 7 mm., within which they pupate. All the cocoons are compactly arranged inside the larval tunnel, into a spindle-shaped mass measuring about 3.8 to 4.8 cm. The larval period is 8 to 10 days.

Three to six days after the formation of the cocoon, the grub pupates. The freshly-formed pupa is uniformly white and measures 5.0 mm. x 1.5 mm. Two days after pupation the eyes assume a reddish-brown colour and a day later they turn black. The whole pupa turns brownish on the fourth day. The pupal period ranges from 5 to 9 days. The total life-cycle of the parasite lasts from 15 to 21 days, the average for 25 specimens being 16.5 days. Parthenogenesis occurs in the species, the progeny in such cases being as usual males.

Hosts other than *Scirpophaga*

The parasites were also collected from caterpillars of *Chilo zonellus* infesting *sorghum*.

Seasonal and regional distributions

The parasites are most active in the field from January to March, but become scarce as the rains set in and are not noticeable during August, September and October. In the cane-growing centres in the Northern-Circars the parasite has not been noted so far.

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ON THE NOMENCLATURE AND SEASONAL FORMS OF *HAPALIA MACHAERALIS* (WALK.) (PYARLIDÆ, LEP.)

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The species now recognised as *Hapalia machæralis* was described by Walker (1859) from a single female specimen from Ceylon under the name *Scopula machæralis*, and from the same locality another female as *Scopula damastesalis*. Lederer (1864) described the species as *Botys egenalis*, supposedly from Venezuela but subsequently shown to be from India. Butler (1880) described one specimen from Formosa as *Asopia rufipicta*, remarking that the species reminded him somewhat of *Botys egenalis*. Moore (1887) described a form as *Ebulea fimbriata*. Swinhoe (1890) described from Burma two seasonal forms as two separate species, one as *Hapalia* (?) *albicostalis* and the other as *Paliga leucanalis*. Hampson (1896) sank all the foregoing species, except *Hapalia albicostalis* Swinh. and *Paliga leucanalis* Swinh., as synonyms of *Pyrausta machæralis*. The species *albicostalis* and *leucanalis* were put by him in the genus *Pionea*. Later, the same author (1903) stated that *Scopula damastesalis* is identical with *Pionea leucanalis*.

The cause of this confusion is due first to the statement of some authors that the middle tibiæ of the male of *machæralis* is without a dilated and tufted groove, while the contrary is true, and second, to the fact that the species shows considerable colour variation according to climatic differences. In the course of rearing several thousands of moths in field-insectaries of the Forest Research Institute, Dehra Dun, in the Central Provinces, South India and the United Provinces, four distinct forms were observed. The pale and ochraceous varieties are hot-dry-summer and hot-wet seasonal forms, while the dark and brick-red varieties are the spring and cold seasonal forms. The two main seasonal forms are tabulated below :—

Dry-hot-summer & hot-wet-seasonal forms	Spring & cold seasonal forms
Asopia rufipicta Butler. *Botys egenalis* Lederer. *Ebulea fimbriata* Moore. *Hapalia albicostalis* Swinh. (new synom.) *Scopula damastesalis* Walk. *Scopula machæralis* Walk.	*Botys suavalis* Walk. *Paliga fuscicostalis* Swinh. *Paliga leucanalis* Swinh. *Paliga rubicundalis* Warr.

The dark and brick-red varieties of moths do not occur at Nilambur, South Malabar.

Venational characters of a series of moths were studied, especially by Beeson and Fletcher. From their notes in the files of Forest Entomologist, it appears that the species should be placed in the genus *Pionea.* The genus *Hapalia* Hübner (1816) type *fulvalis* is however the earlier name.

Joannis (1929) split up *machæralis* forms into two distinct genera, placing some under *Mesographe damastesalis* Walk., and the others under *Pyrausta machæralis* Walk. His differentiation in the recognition of the two forms is based mainly on the structure of the maxillary palpi, stating that in *Mesographe damastesalis* it is triangular with a scaly tuft, while in *Pyrausta machæralis* it is filiform. In all forms of both the sexes bred at Dehra Dun, the maxillary palpi are dilated and have scaly tufts, and not filiform as stated by Joannis for the forms considered by him to be *machæralis,* which may perhaps be a distinct species altogether. His other species, *Mesographe damastesalis,* is undoubtedly *Hapalia machæralis.* He sank *Hapalia* as synonym of *Mesographe* on the basis of priority. But it is already recognised that *Hapalia,* type *fulvalis, Mesographe,* type *forficalis* and *Pyrausta,* type *cingulata,* are three distinct genera. Pierce and Metcalfe (1938) described the genitalia of these three type species. The slide preparations of the genitalia of *Hapalia machæralis* in the Forest Research Institute Museum definitely show that this species bears a greater affinity to *Hapalia* than to the other genera, *Mesographe* and *Pyrausta.* Evidently the species *machæralis* falls under *Hapalia* and not under *Mesographe.*

The known distribution of *machæralis,* besides India and Burma, is Australia, Ceylon, Formosa, Indo-China and Java.

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ANATOMY AND MUSCULATURE OF THE MOUTH-PARTS OF *SCIRPOPHAGA NIVELLA* (PYRALIDÆ), WITH A DISCUSSION ON THE COILING AND UNCOILING MECHANISMS OF THE PROBOSCIS IN LEPIDOPTERA

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CONTENTS

I. INTRODUCTION

Detailed study of the imaginal mouth-parts of *Scirpophaga nivella* (Fabr.) was undertaken as a preliminary to a comprehensive work on the mouth-parts of Lepidoptera in general. This particular insect was selected because, being a common pest of sugar-cane, it is readily available, and the structure of the proboscis of this species turned out to be so interesting that we were led to analyse and examine the whole mechanism of lepidopterous proboscis afresh. Thus the present paper embodies, besides the description of the mouth-parts of *S. nivella* in some detail, a theoretical analysis of the biomechanical principles involved in the working of the proboscis, based on the structural details found in text-books, as well as observed by us in about a dozen species of other Lepidoptera.

II. MATERIAL AND TECHNIQUE

Specimens of *Scirpophaga nivella* were either collected as adults or were reared from pupæ. The chitinous structure of the mouth-parts was studied by mounting the dissected organs in euperal, after dissolving out the soft parts with caustic potash solution. In making mounts in euperal, dehydration was not necessary and the structures were transferred from

*The MS. of this paper was prepared for publication in the laboratory of the Imperial Entomologist, New Delhi.

water to the clearing medium, consisting of a mixture of clove oil and acetic acid, and then mounted. Euperal has an added advantage in that visibility is improved on account of its low refractive index.

For dissection, specimens fixed in warm alcoholic Bouin's picro-formol and kept in 90% alcohol for a long time were used. Keeping them in water for several hours rendered dissection easier. Free-hand sections were made in order to study the muscles, as the hard chitin of the head-capsule does not easily yield to the microtome.

The proboscis-muscles were studied by making permanent whole mounts of the proboscis after bleaching it with hydrogen peroxide.* Microtome sections, about 6 microns thick, were also made after softening the chitin with diaphanol.

III. THE STRUCTURE OF THE MOUTH-PARTS OF *S. nivella*

The mouth-parts consist, as usual, of (1) an unpaired labrum, (2) a pair of mandibles, (3) a pair of maxillæ forming the proboscis and (4) a pair of second maxillæ or the labium. All these structures present different

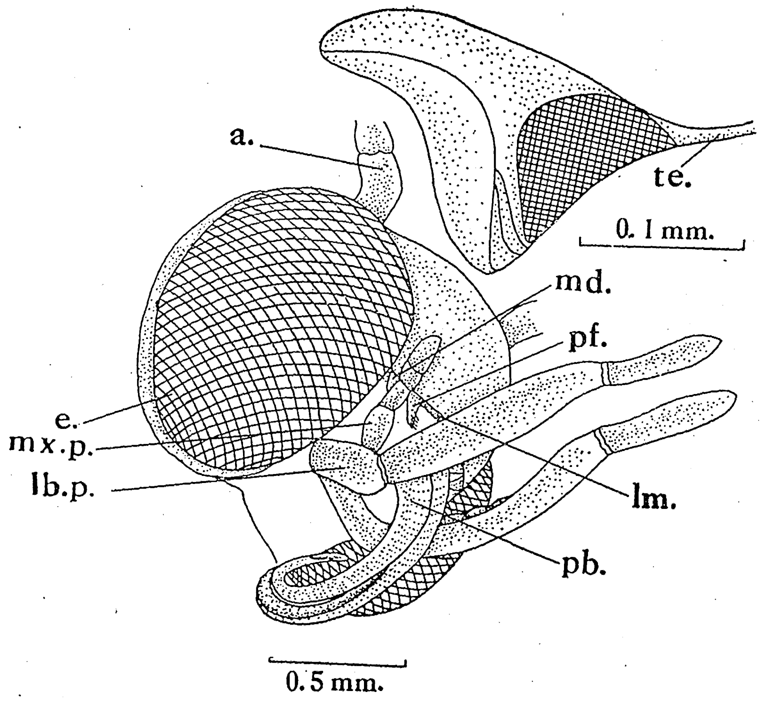

Fig. 1. Head of *S. nivella* (dorso-lateral view) *a.* antenna; *e.* eye; *lm.* labrum; *lb.p.* labial palp; *md.* mandible; *mx.p.* maxillary palp; *pb.* proboscis (galea), *pf.* pilifer; Mandible of *S. nivella* with a piece of tendon (*te.*) attached to it, more highly magnified is shown separately.

* For further details of the techniqué vide PRADHAN 1938, *Rec. Indian Mus.*, 40 : (4) : 342

degrees of reduction and specialisation and are described here in some detail; the actual significance of each structural detail, however, is being postponed till a more comparative work is possible.

Labrum.—The labrum is a narrow membranous sheet. Laterally it bears on each side a lancet-shaped process, called the pilifer (Fig. 1), which projects downwards and bears a large number of bristles.

Mandibles.—In a frontal view, the mandibles are visible (Fig. 1, *md.*) on either side of the pilifers, although slightly covered by the latter. Each mandible is typical in structure; its base as usual bears a slight condylar thickening on its inner edge and a long tendon (*te.*) attached to its outer angle. The feeble sclerotisation, however, shows that they can hardly be of any effective use, and are therefore merely of vestigial nature.

Maxillæ.—In spite of its specialised modification, the maxilla has not lost its typical structure and one can still distinguish its various parts. The stipes (*st.*) articulates laterally with the head-capsule and is thus situated ventro-posteriorly to the mandible. It is a hollow triangular structure with its apex directed backwards and upwards and its cavity opening into the head-capsule. The proximal end of the stipes bears a small chitinous structure, which undoubtedly represents the cardo (*cd.*). The stipes and the cardo are together lodged externally into a shallow concavity in the head-capsule, forming a kind of condylar articulation

The distal end of each stipes bears one half of the proboscis which is interpreted by all workers as the galea (*ga.* or *pb.*) of the typical maxilla; this interpretation is strongly supported by the nature of its insertion and position in this insect. It is interesting to note that at the base of the proboscis we find a small chitinous structure, strongly resembling typical lacinia (*lc.*) in shape and position. It appears that, although the whole of lacinia has been almost completely incorporated in the base of the proboscis or galea, its tip is still slightly separate, indicating its identity. This separate identity of lacinia in this Pyralid is to be carefully noted, in view of Philpott's statement (1927) that this organ is absent in all Lepidoptera except in the Micropterygoidæ. The proboscis of *S. nivella* shows an interesting case, in which the lacinia is seen in the

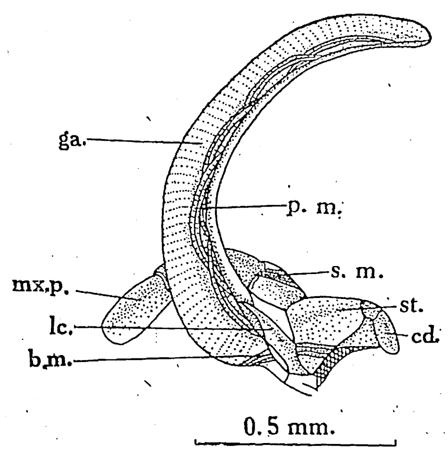

Fig. 2. Maxilla of *S. nivella* and its intrinsic muscles. *b.m.* basal muscle; *cd.* cardo; *ga.* galea; *lc.* lacinia; *mx.p.* maxillary palp; *p.m.* longitudinal proboscis muscles; *s.m.* segmental muscle of the palp; *st.* stipes.

actual process of being incorporated in the base of the galea, as was suspected by Berlese (1910). The detailed structure of the galea will be described hereafter.

Ventro-external to the base of the galea, the stipes bears the 4-segmented maxillary palpus (*mx. p.*), the entire surface of which is covered with a large number of longitudinally-fluted scales of varying length. In the living condition the palpi remain permanently flexed upwards as a pair of brushes on either side of the proboscis.

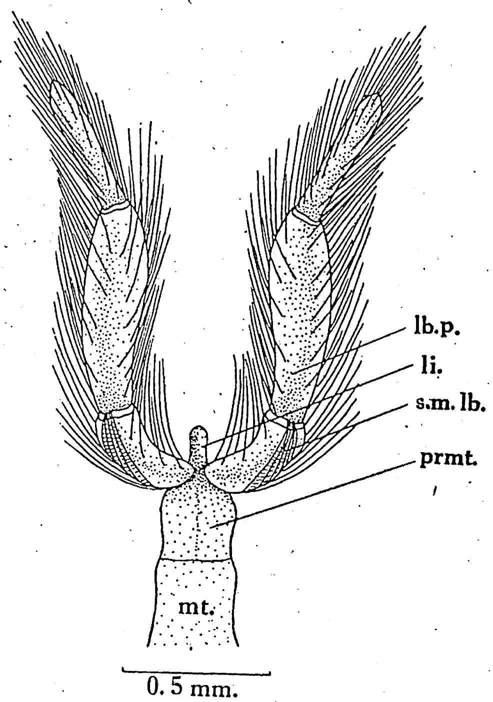

Fig. 3. Labium of *S. nivella*. *lb.p.* labial palp; *li.* ligula; *mt.* post-labium; *prmt.* prementum; *s.m. lb.* segmental muscle of the palp.

Labium.—Despite a great reduction in the sclerotisation of the labial region (Figs. 1 & 3), we can still distinguish the partially sclerotised pre-labium from the entirely membranous post-labium. Besides the degree of sclerotisation, the distinction between these two regions is established by the attachment of the palpal muscles (Fig. 4, *lb., l.m., lb. d.m.*) on the proximal margin of the pre-labium, where a faint labial suture can also be distinguished. The pre-labium is further divided into a broad prementum (*prmt.*) and a narrow ligula (*li.*), which is a small hollow median structure. The post-labium (*mt.*) is entirely membranous and extends obliquely from the labial suture on the posterior margin of the prementum almost to the margin of the foramen magnum, where its posterior limit is defined by invagination of the post-tentorial pits. The labial palps (*lb.p.*) are very well-developed, three-segmented structures.

Proboscis.—A perusal of the literature on the subject indicates that the lepidopterous proboscis has been inadequately studied. A detailed account of the structure is, therefore, in our opinion worthy of record.

The proboscis of *Scirpophaga nivella* is formed of two halves, which, as already stated, represent the galea of the maxillæ. The two halves are rather loosely held together. In the normal condition of rest, the proboscis remains coiled round a horizontal axis, the curvature being along

its ventro-posterior wall. In permanent preparations of the coiled proboscis, we find that the proboscis generally forms one and a half to two coils. The length of the proboscis is a little more than one millimeter, while its dorso-ventral diameter gradually diminishes from about 90 microns at its base to about 50 at the tip.

An examination of the two halves of the proboscis in a permanent preparation reveals that each half is really a hollow double-walled chitinous gutter. The diameter of the gutter decreases from about 60 microns at the base to about 40 at the tip. The shape of the gutter is maintained by a row of discrete thickened bands of chitin, which lie all along the gutter on its inner wall. The number of these chitinous bands is roughly estimated as being 300—500 on each side. It is to be noted that these chitinous bands are confined in the inner wall of the gutter; the outer wall is formed of a continuously chitinised membrane with no separate chitinous bands. In this respect it shows a condition different from that of the proboscis of a butterfly like *Danaida* sp., in which Burgess (1880) described that the chitinous rings extend all round the proboscis but do not extend into the groove; in other words, the chitinous bands form the outer wall, while the inner wall is free from them. The outer wall of the proboscis is fairly stretched while the inner wall shows irregular foldings. As the proboscis coils as a whole in a vertical plane, we can distinguish an anterior and a posterior wall of the complete proboscis. A close examination of the base of the proboscis reveals two interesting features: (1) that the convex (outer) surface at the base of the proboscis is definitely weak up to a length of about 130 microns, (the significance of this differential chitinisation is considered later), and (2) that the lacinia as already described, can be distinguished at the base of the proboscis at its dorso-medial edge.

IV. The musculature of the mouth-parts of *S. nivella*

A study of the musculature of the mouth-parts shows that the typical muscles found in a generalised insect have undergone much specialisation and reduction in this species. Furthermore, the enormous development of eyes on either side of the head-capsule leaves little space for the accomodation of muscles in this region. On account of this concentration, the dissection of these muscles presents much difficulty. The various muscles are described below.

The mandibular muscles.—The mandibular muscles (Fig. 4) have undergone almost complete reduction, being represented in each mandible only by a few muscle-fibres at the end of a long tendon. Each set of muscle-fibres originates near the ventro-posterior corner of the ocular ridge and soon converges to a fine tendon. This tendon passes forwards externally to the muscles of the maxilla (vide *infra*) and is inserted at the outer angle of the mandible. From the position of its insertion it is clear that

it is a vestige of the abductor muscle (*md. abd.*).

The reduction of the mandibular muscles is not unexpected, as the mandibles seem hardly to have any function at all in this moth. It is, however, interesting to note that while the abductor muscle persists in a very reduced condition, the adductor, comparatively more well developed in a generalised insect, is altogether absent.

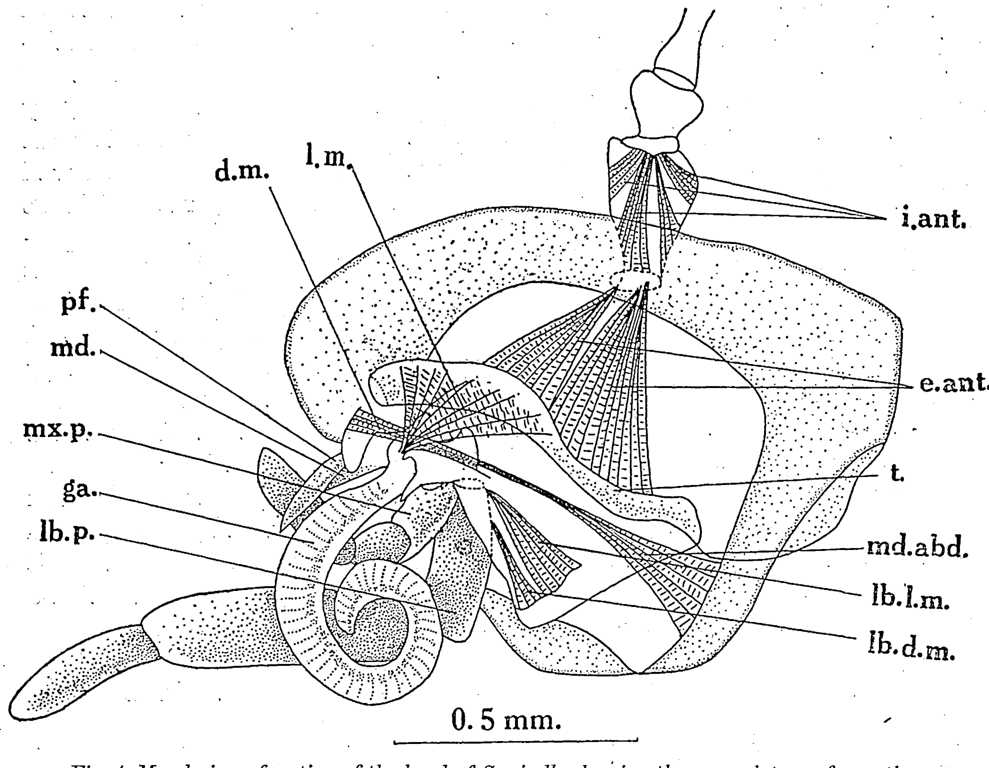

Fig. 4. Mesal view of section of the head of *S. nivella* showing the musculature of mouth-parts. *d.m.* depressor muscle of maxilla; *e. ant.* extrinsic muscles of antenna; *ga.* galea or proboscis; *i. ant.* intrinsic muscles of antenna; *lb. d.m.* depressor muscle of labial palp; *lb. l.m.* levator muscle of labial palp; *lb. p.* labial palp; *l.m.* levator muscle of maxilla; *md.* mandible; *md. abd.* abductor muscle of mandible; *mx. p.* maxillary palp; *pf.* pilifer; *t.* tentorium.

The muscles of the maxilla.—The muscles of the maxilla can be described under two categories: (i) the extrinsic and (ii) intrinsic muscles. There are two extrinsic muscles, which from functional point of view, can be described as (1) levator, and (2) depressor muscles. Schmitt (1938) interpreted these muscles as posterior and anterior "tentorial proboscis extensors" respectively. As discussed later, we do not agree with this interpretation. There is no representative in *S. nivella* of what Schmitt designates as the "cranial proboscis extensor". The levator muscle (*l.m.*) originates in a fan-like fashion from the anterior arm of the tentorium

and converges almost to a point at its insertion on the anterior margin of the stipes near the base of the proboscis. The contraction of this muscle, as indicated by its position, will naturally raise the maxilla as a whole. The depressor muscle (*d.m.*) originates from a small ridge situated anteriorly to the dorsal tentorial pit, and after passing backward and downward externally to the levator muscle, is inserted on the anterior surface of the cardo. Thus, as shown in fig. 4, the depressor muscle is situated crosswise to the levator and its contraction, therefore, opposes the action of the levator muscle, *i.e.*, depresses the maxilla as a whole. The levator and depressor muscles, thus act as forces on the two arms of a lever, formed by the cardo and the stipes together moving in a small cavity on the genal area.

The intrinsic muscles of the maxilla comprise the muscles of the proboscis and the maxillary palpi.

The muscle associated with the maxillary palp (fig. 2, *s.m.*) is situated mainly within its basal segment. The muscle-band originates from the posterior wall of the basal segment and is inserted on the inner margin of the proximal edge of the second segment. Thus the contraction of this muscle bends the palpus.

The proboscis muscles.—The musculature of the proboscis is interesting in as much as it is different from that in other Lepidoptera described in modern text-books. In *S. nivella* we find two separate sets of muscles : (1) the basal muscle and (2) the intrinsic proboscis muscles. The basal muscle (Fig. 2, *b.m.*) is a small muscle taking its origin from the stipes and running obliquely forward to be inserted on the dorsal wall of each half of the proboscis, just anterior to the weaker portion of the chitin at the base. From its attachment and position it appears to be a representative of the stipital flexor muscle of the galea of a generalised insect.

The muscle bands (Fig. 2, p.m.) situated within the main body of the proboscis as usual do not form a continuous compact muscle but consist of several short muscle bands distributed throughout the whole length of the proboscis, each muscle-band stretching across several (16 or more) thickened bands of chitin. It is not possible to distinguish between the points of origin and insertion of these muscle-bands as they taper at both ends into similar tendons, which are attached to the posterior wall of the proboscis. They are invariably stretched along the length of the proboscis. It is also distinctly noticeable that these muscles are much more densely crowded along the posterior than along the anterior wall. This arrangement of muscle bands, especially their lengthwise disposition in *S. nivella*, is very peculiar in view of the fact that the proboscis muscles in other Lepidoptera, as described in text-books (Imms 1938 and Snodgrass 1935), take their origin from near the middle line of the anterior wall and run obliquely distalwards to be inserted on the posterior wall.

The labial muscles.—There are three sets of labial muscles : (1) the levator of the palpus, (2) the depressor of the palpus, (3) the segmental muscle of the palpus.

The levator (Fig. 4, *lb. l.m.*) and depressor (*lb. d.m.*) muscles of the palpus take their origin close together from the posterior margin of the prementum and run forwards, the levator being inserted on the anterior and the depressor on the posterior margin of the proximal edge of the first segment of the labial palpus. The separate identity of these two muscles is made out only in a sagital section, as they cover each other and cannot be distinguished when viewed from the dorsal or the ventral side. Of the two, the levator muscle is stronger and consists of a larger number of muscle-bands. The difference in size between the levator and the depressor muscles seems to be correlated with the fact that the palpus is kept almost permanently flexed upwards thereby requiring a stronger levator. The depressor is not so highly developed as the palpus is less frequently depressed and when it is, the action is aided by the relaxation of the levator.

The segmental muscle (Fig. 3, *s.m.lb.*) of the palpus originates from the posterior wall of the basal segment and converges to be inserted on to the proximal margin of the second segment. The contraction of this muscle seems to bring about a bend between the first and second segments.

V. THE COILING AND UNCOILING MECHANISM OF THE PROBOSCIS

The working of the lepidopterous proboscis has been an unsolved problem so far. The state of our knowledge may be gathered from the following quotations from two well-known text-books.

Imms (1938) writes "When not in use the proboscis is spirally coiled and stowed away beneath the thorax............ The interior of each half of the proboscis is hollow and occupied throughout its length by a nerve and a trachea, but the bulk of the cavity accommodates two sets of muscles which diagonally cross it. From their attachment, the action of these muscles would result in shortening the posterior wall of the maxilla and produce the spiral coiling of the organ. The method of extension of the latter does not appear to be clearly understood, and it has been variously suggested to take place by means of its own elasticity or by blood pressure. Burgess suggests that we have failed to interpret some muscular mechanism for the purpose."

Snodgrass (1935) states " When the proboscis is not in use it is tightly coiled beneath the head, but it can be completely extended in response to a food stimulus. The mechanism of extension and coiling, however, is not well understood. The outer wall of each half of the proboscis shows a closely ringed structure produced by a succession of sclerotic arcs alternating with narrow membranous spaces. This structure probably

allows the coiling of the tube. Within each half of the latter is a series of short muscle-fibres arising near the middle of the outer wall and extending obliquely distad and toward the inner edge of the concave side of the organ, on which they have their insertions. The muscles occupy the entire length of each half of the proboscis, and their arrangement suggests that they serve to coil the proboscis. Unless there is some mechanical principle here involved that is not yet understood, we must assume that the proboscis is extended by blood pressure in the same way that a toy paper " snake " is unrolled by inflating it, and it must be observed that the natural uncoiling of lepidopterous proboscis, beginning at the base and progressing toward the tip, has a striking resemblance to the unrolling of the inflated " snake". The mechanism for creating the assumed blood pressure, however, is not evident."

The unsatisfactory state of our knowledge evident from the above quotations coupled with the difficulties we had to face in explaining the structure and working of the proboscis of *Scirpophaga nivella* led us to examine the whole problem afresh. We studied the structure of the proboscis in a few other moths and butterflies, namely, *Utetheisa pulchella* (Linn.), *Noctuelia floralis* Hübn., *Earias fabia* (Stoll.) and *Argyria sticticraspis* Hmpsn., *Danaida chrysippus* (Linn.), *D. limniace* (Cram.), *Precis almana* Linn., *P. lemonias* Linn., *Catopsilla pyranthe* (Linn.) and *Delias eucharis* Drury. As a result of this study we have been able to offer in the following pages an explanation of this puzzling problem, although in so doing we have been led to a view which is diametrically opposed to that held by all the previous workers.

Structurally, the proboscis of nine out of the eleven species examined by us agree in all essentials with the text-book descriptions, but *S. nivella* which we have described in detail in this paper along with *A. sticticraspis* happens to present a special case different from all other moths examined by us or described in literature. Therefore, the mechanism in the former group is being interpreted as that of typical Lepidoptera while that of the latter two species as an exceptional case.

(*a*) *Mechanism in typical Lepidoptera*

The description of the general structure of a typical lepidopterous proboscis is available in most of the modern text-books. It consists of two identical gutter-shaped lateral halves held opposed to each other by a series of inter-locking grooves and ridges along the margins of the two gutters (Figs. 5, 6a & 6b). Each half is essentially a hollow tubular structure, the wall of which shows a closely ringed appearance due to a series of transverse bands of thickened chitin along its entire length. These bands sometimes form complete rings and at other times remain only incomplete arcs. The musculature of each half consists of thick

short muscle bands stretched obliquely within the cavity of the tubular structure. These muscle bands are distributed almost throughout the whole length. They take their origin (O) on the convex anterior wall and run distally to be inserted on the concave posterior wall. Besides the muscles, the cavity also encloses a nerve and a trachea and gets the supply of hæmocœlic fluid. The problem is to interpret the working *i.e.*, the coiling and uncoiling of this structure.

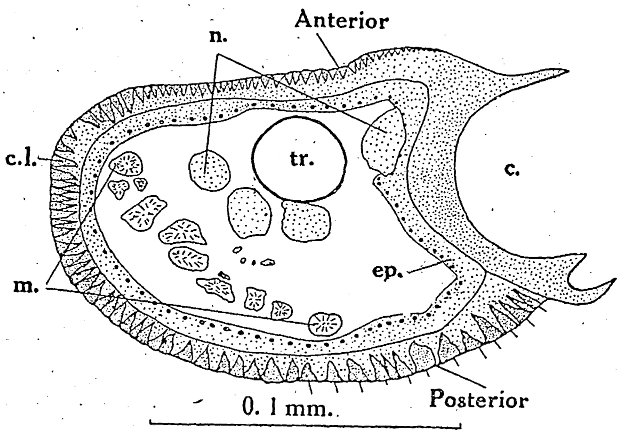

Fig. 5. Transverse section of proboscis (one-half only) of *Precis almana* Linn. *c.* gutter (food-channel); *c.l.* chitinous layer; *ep.* epithelium; *m.* muscles; *n.* nerves; *tr.* trachea.

For the coiling and uncoiling movements of a hollow tube like each half of the proboscis, only three kinds of forces can be expected to be effective, *i.e.*, (*i*) the variation of pressure, liquid or gaseous, within the cavity of each half of the proboscis, (*ii*) the elasticity of the proboscis and (*iii*) the muscular action within or outside the proboscis. Now let us consider each of these factors. The only possibility of creating fluid pressure can be with the help of the hæmocœlic fluid (blood) or by gaseous pressure by means of air in the trachea. Both these possibilities are very suggestive and the blood-pressure has actually been suggested by some previous workers (Snodgrass, 1935 and Schmitt, 1938) as an active agency in bringing about uncoiling, but a careful consideration reveals the following serious difficulties in accepting this view : There is no mechanism whatsoever for creating a liquid or gaseous pressure within the proboscis. In the definite absence of any such mechanism it is only a speculation to think of a fluid pressure. Schmitt (1938), however, tried to interpret the existence of a "pressure chamber" with a "valve arrangement" in the stipital region at the base of the proboscis, meant for creating a liquid pressure within each half of the proboscis. We are, however, unable to support Schmitt's observations and contentions on either structural or experimental observations. Schmitt stated that as the muscles inserted on the stipes draw the stipes upwards, the tubular part of the stipes becomes a closed cylinder which he calls the "pressure chamber" and that with further contraction of the same muscles, the closed cylinder of the stipital portion is pressed against the recurved flange of the gena and

the pressure thus created within the stipes causes an extension of the proboscis.

We are, however, unable to appreciate Schmitt's view that the stipes can be converted into a liquid-tight compartment. The muscles which Schmitt describes as being inserted on a " median flat sclerite " are actually inserted within the cavity of the stipes at least in the species studied by us.

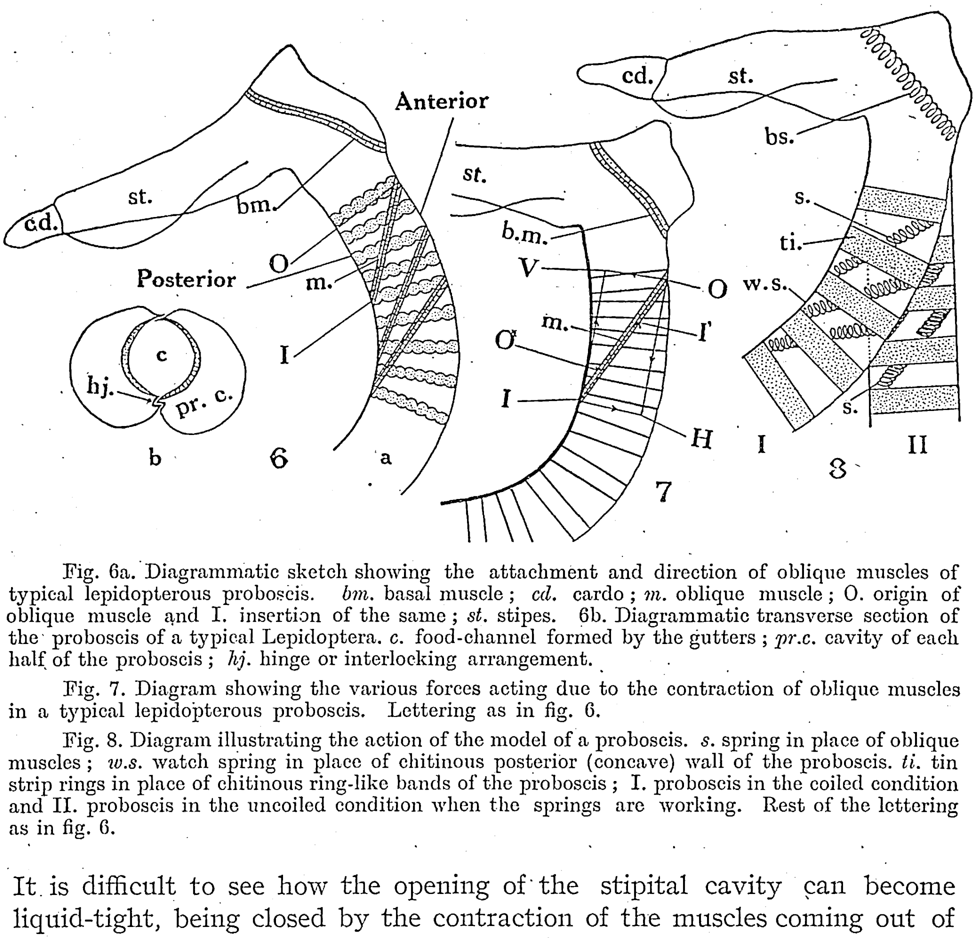

Fig. 6a. Diagrammatic sketch showing the attachment and direction of oblique muscles of typical lepidopterous proboscis. *bm.* basal muscle ; *cd.* cardo ; *m.* oblique muscle ; O. origin of oblique muscle and I. insertion of the same ; *st.* stipes. 6b. Diagrammatic transverse section of the proboscis of a typical Lepidoptera. *c.* food-channel formed by the gutters ; *pr.c.* cavity of each half of the proboscis ; *hj.* hinge or interlocking arrangement.

Fig. 7. Diagram showing the various forces acting due to the contraction of oblique muscles in a typical lepidopterous proboscis. Lettering as in fig. 6.

Fig. 8. Diagram illustrating the action of the model of a proboscis. *s.* spring in place of oblique muscles ; *w.s.* watch spring in place of chitinous posterior (concave) wall of the proboscis. *ti.* tin strip rings in place of chitinous ring-like bands of the proboscis ; I. proboscis in the coiled condition and II. proboscis in the uncoiled condition when the springs are working. Rest of the lettering as in fig. 6.

It is difficult to see how the opening of the stipital cavity can become liquid-tight, being closed by the contraction of the muscles coming out of the same opening into the head-cavity. It may also be noted that a valve meant for checking the flow of a liquid in the animal kingdom (*e.g.*, valves within the vertebrate heart and arteries, ostia of arthropod heart, etc.) is always closed by the internal pressure of the liquid of which the flow is intended to be checked by the valve. In Schmitt's description of the valve within the stipes, on the other hand, only two chitinous structures are taken to be pressed against each other by muscular contraction. The existence of such a valve, is not demonstrated.

Despite above-mentioned difficulties in accepting Schmitt's contentions, we tried to test his interpretations experimentally. We caught four specimens of *Danaida chrysippus* (Linn.) and completely punctured their stipes with the help of a needle (under the binocular microscope) without killing the butterfly. In all the four cases we found that after recovery from the shock due to injury, within half an hour or so, the butterfly began to uncoil the proboscis in response to mechanical irritation or food stimulus. We think that this experiment leaves no doubt that the fluid pressure within the stipes does not cause an uncoiling of the proboscis at all.

Furthermore, granting that fluid pressure were the uncoiling agency, we should expect each half of the proboscis to be very much swollen up in the uncoiled condition and definitely compressed in the coiled condition. Observations both on living and fixed specimens definitely confirm that no such changes actually take place in the proboscis.

It may be repeated that Snodgrass (1935) compares the uncoiling of the lepidopterous proboscis with that of the toy paper " snake " ; but he does not take into consideration the important fact that, whereas the tube of the paper " snake " is definitely deflated during the coiled condition and becomes fully inflated in the uncoiled state, there is no such alteration in girth in the case of the lepidopterous proboscis. On the other hand, as is shown below, the lepidopterous proboscis resembles the toy paper " snake " in its coiling and not in its uncoiling mechanism.

As regards the elasticity of the proboscis being responsible for its uncoiling, the following observations show beyond doubt that elasticity tends to coil the proboscis rather than bring about its uncoiling.

a. After dissolving out the muscles by boiling the proboscis of any Lepidoptera in caustic potash solution, we find that the proboscis remains in the usual coiled condition. When the coils of such a proboscis are mechanically opened and then released, the proboscis returns to its normal coiled condition. This coiling back of the proboscis is undoubtedly due to elasticity of the chitinous portion of the proboscis.

b. A close anatomical study of a lepidopterous proboscis (say *Precis almana* Linn.) shows that the structure is specially meant for rendering the organ elastic. There is a definite differential chitinisation in the anterior and posterior walls of the proboscis (Fig. 5). In most of the butterflies examined, the posterior wall is much more rigidly built than the anterior wall. It appears that the posterior wall has the same function and relation as the spring-wire running along the concave side of the " paper-snake." which remains coiled due to elasticity of this spring-wire. Observations on living butterflies confirm the foregoing contention. By forcibly opening the proboscis of any living butterfly and then releasing it, one can easily observe the mechanical rapidity in the coiling of the

proboscis, which is most probably due to its elasticity rather than to any vital agency like muscular contraction or changes in the fluid pressure.

The agency of the fluid pressure being rejected in *toto* and that of elasticity being understood to bring about coiling, let us see if the uncoiling agency is the force of muscular contraction, although this force has been generally interpreted as a coiling agency.

For a clear understanding of the possible functions of the muscular force, following structural points should be particularly noted in addition to the general description of the proboscis given above.

Firstly there is a differential chitinisation of the anterior and posterior walls of the proboscis (Fig. 5). In the butterflies examined, there appears to be little doubt that the posterior wall, despite its ringed appearance, is definitely rigid and is incapable of allowing any shortening of its length; the structure of the anterior wall on the other hand is such that the chitinous rings described by the various workers are separated by comparatively foldable and membranous spaces. Thus it is reasonable to conclude that the elasticity of the proboscis is lodged within the posterior wall, which functions as the spring-wire of the toy "paper snake", and keeps the proboscis coiled, whereas the anterior wall is foldable and admits of uncoiling. Previous workers have not appreciated the differential chitinisation stressed by us, although as will be shortly clear this fact is of fundamental significance in interpreting functions of the proboscis muscles.

Secondly the point of attachment (Fig. 6*a*, I) of the oblique muscle fibres on the posterior wall is distal to its point of attachment (O) on the anterior wall.

Thirdly the chitinous rings of the proboscis are rigid continuations of the posterior wall and even their anterior portions which afford points of origin to the oblique muscles, do not yield to the bending force of these muscle fibres.

With the foregoing data let us try to understand the mechanics of the proboscis muscles.

The direction and attachment of the muscles have been diagramatically represented in Fig. 6, while the direction in which the forces work have been shown in fig. 7. When the muscle (m) contracts, there is a pull on both the points 1 & O in the direction of the line I O. Now the force OO′ can be resolved into its components OV and OH respectively. Similarly, the force II′ can be resolved into the components IH and IV. Of these four components, the component OH is opposed by the unbendable nature of the chitinous bands on which O lies and which do not bend in the direction OH, whereas the component IV is opposed by the unfoldable rigidity of the posterior wall of the proboscis. Thus the two effective components OV and IH form a couple OV, IH, tending to uncoil the proboscis.

It may also be noted that the component IV is greater than the component IH, as is apparent from the comparative lengths of the lines which represent in direction and magnitude these components in the diagram. It is, therefore, clear that if the component IV is not opposed by the rigidity of the posterior wall, then this component would be more effective than IH and the contraction of the muscle would bring about the coiling of the proboscis. Evidently, previous workers did not take into consideration the rigidity of the posterior wall, which does not admit of any shortening in its length and it is this omission which has led them to the conclusion that oblique muscles bring about the coiling of the proboscis.

The theoretical arguments put forth in the above paragraph have been more than amply demonstrated by an artificial model shown in fig. 8.

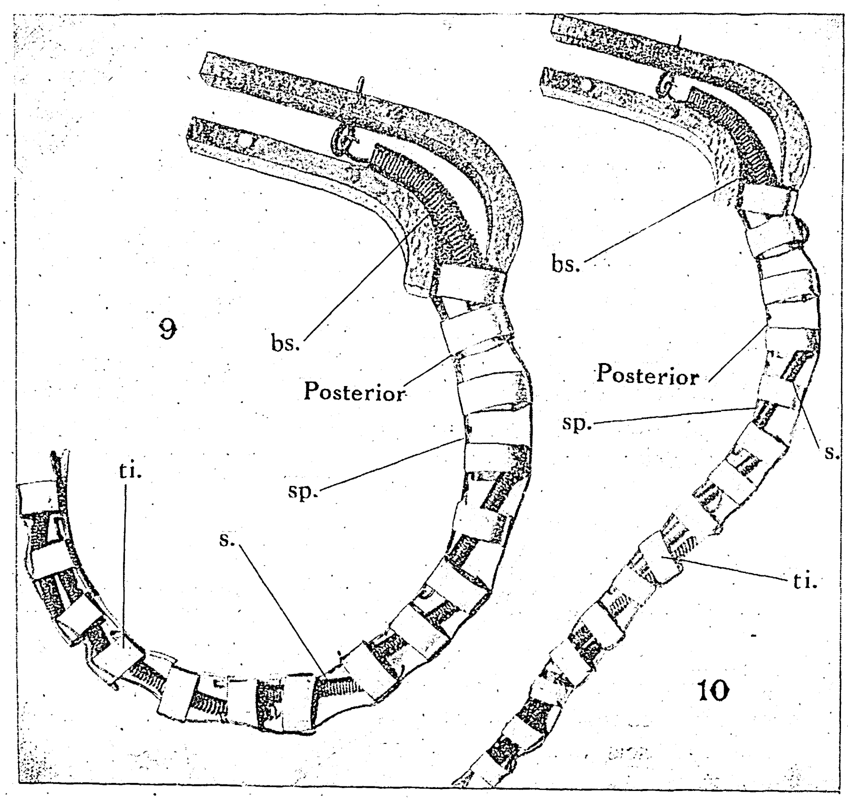

Fig. 9. Photograph of mode (coiled condition, springs relaxed). *bs.* spring in place of basal muscle ; *sp.* watch spring in place of posterior (concave) wall of the proboscis. Rest of the lettering as in fig. 8.

Fig. 10. The same as fig. 9. (uncoiled condition, springs working). The magnification of this photograph is less than in fig. 9. Lettering is the same.

In this model, which represents only one half of the proboscis, the chitinous rings are represented by a series of tin strip rings soldered along a piece of

clock-spring (*w.s.*) representing the posterior wall of the proboscis. Within the ringed tube thus constructed, the oblique muscles of the proboscis have been represented by a set of springs S ; when these springs are contracted by means of hooks in the same direction as the oblique muscles are attached, the contraction of these springs brings about the uncoiling of the model in exactly the same way as the lepidopterous proboscis uncoils itself (Figs. 9 and 10). There can hardly be any more convincing evidence in favour of our interpretation that the oblique muscles bring about uncoiling. Of course it may be mentioned once more that in the model also the posterior wall has been made so rigid as not to admit of any shortening of its length. It has also been demonstrated by means of a similar model that in case the anterior wall is rigid instead of the posterior the same oblique muscles tend to coil the proboscis.

Thus contrary to all the prevailing belief, we come to the conclusion that the uncoiling of the proboscis is brought about by the contraction of the oblique muscles, whereas the coiling is the result of the elasticity of the chitin of the coiled posterior wall.

In support of our view, we may also point out the fact that the proboscis remains coiled in the normal condition of rest. In case the contraction of the oblique muscles were to bring about coiling, the muscles will have to remain contracted throughout the period when the proboscis is at rest. This continued strain on the muscles during the period of rest is unlikely. Evidently the previous workers have unconsciously erred in maintaining that the ringed structure allows the coiling of the organ. What ought to be definitely realised is that the proboscis in its natural and absolutely unstrained condition is a coiled structure, which due to the foldable nature of its anterior wall allows of uncoiling when the oblique muscles contract.

(*b*) *Mechanism in* S. nivella

As already stated, proboscis of *S. nivella* and *A. sticticraspis* presents an exceptional case, not recorded so far, in the following peculiarities :

1. The oblique muscles which have been interpreted so far by every worker, including Schmitt (1938), as causative agents in bringing about the coiling of the proboscis and which have been described by Imms as "diagonally" crossing the proboscis and by Snodgrass as "extending" obliquely within each half of the proboscis, are absent in *S. nivella*.

2. The musculature in *S. nivella* consists of two separate muscles for two different functions, *viz.*, (1) of coiling and (2) of uncoiling the proboscis, which processes are brought about in the manner described below.

3. Unlike other Lepidoptera, there is little differential chitinisation in the wall of the proboscis and whatever little there is, it is in the reverse

direction, the anterior wall being more chitinised than the posterior.

Coiling.—The coiling of the proboscis in *S. nivella* is brought about by the contraction of a set of muscles in the proboscis as well as by the elasticity of the proboscis. The muscles in the proboscis of *S. nivella* differ from the oblique muscles in that they do not run obliquely within the proboscis, but are stretched longitudinally and are situated much more closely, nearer the posterior than the anterior side of the proboscis. Thus there remains little doubt that the contraction of these muscles brings about a shortening of the posterior wall, which unlike in other Lepidoptera, is foldable in *S. nivella*.

The fact that the elasticity of the proboscis brings about or at least helps the coiling of the organ is more than fully proved by the fact that after dissolving out all the muscle-fibres with the help of caustic potash solution, the proboscis still remains coiled and that if it is artificially uncoiled and then released it returns almost to its original coiled condition. It must, however, be kept in mind that the elasticity of proboscis in the case of *S. nivella* can be expected to be in the anterior wall and not in the posterior wall, as in other lepidoptera.

Uncoiling.—The uncoiling of the proboscis is evidently brought about by the so-called basal muscle. The contraction of this muscle pulls back the anterior wall of the proboscis, this being rendered possible by a definite weakening of chitin, already described, proximally to the insertion of the basal muscle. The pulling back of the anterior wall of the proboscis naturally brings about the uncoiling of the short proboscis of *S. nivella*.

VI. Acknowledgments

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VII. Summary

Detailed account of the imaginal mouth-parts of *Scirpophaga nivella* (Fabr.) and of coiling and uncoiling mechanisms of lepidopterous proboscis forms the subject of the paper.

The new facts brought to light by this study of the mouth-parts are :

1. The lacinia which is believed to be absent in all Lepidoptera except the Micropterygidæ is distinguishable in this Pyralid also. This insect represents an interesting stage, in which the lacinia is half-way in the process of incorporation with the base of the galea. This study thus affords a direct support to the suggestion of Berlese (1910) about the fate of lacinia in Lepidoptera.
2. A pair of minute mandibles with reduced mandibular abductor muscles is present in this species.

The study of the proboscis-mechanism has led to the following conclusions :

(1) The oblique muscles of the proboscis, so far interpreted as the coiling agencies, do actually uncoil the proboscis.

(2) The coiling is brought about by the elasticity of the chitinous wall of the proboscis.

(3) Blood pressure which had been suspected by others and explained by Schmitt (1938) to be the uncoiling agency has nothing to do with the uncoiling of the proboscis.

(4) The proboscis of *S. nivella* presents an exceptional case. In this insect there are no oblique muscles so common in other Lepidoptera. The coiling is brought about partly by a set of longitudinal muscles and partly by the elasticity of the chitin itself. The uncoiling is brought about by basal muscle.

Thus the chief importance of this paper lies in the explanation of the so far puzzling problem of the coiling and uncoiling mechanisms of lepidopterous proboscis.

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HOST-SELECTION BY *SPATHIUS CRITOLAUS* NIXON, AN IMPORTANT PARASITE OF *PEMPHERULUS AFFINIS* (FAUST) IN SOUTH INDIA

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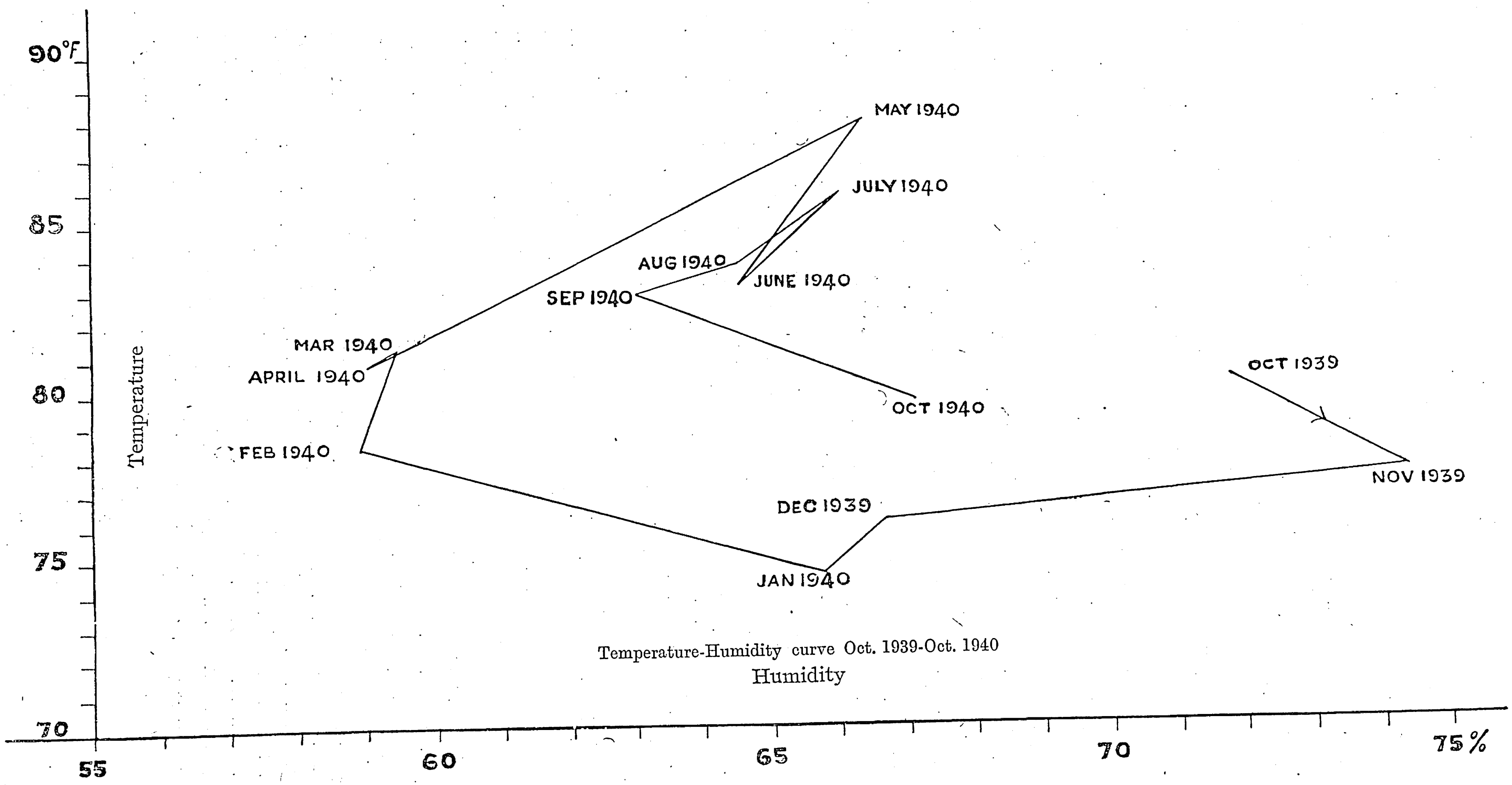
INTRODUCTION

One of the most notable developments in the field of insect parasitism is the increasing attention paid to the problem of host-selection. Such a selection has been variously argued as merely due to the physiological urge of a gravid female for releasing her mature eggs, prompted by instinct or sensory impressions. Recent studies by Salt (1935) and Lloyd (1938) have shown that the parasite female does not adopt a random distribution of her progeny among its host population, without reference to the nature and condition of the hosts but displays considerable discriminatory faculty in the choice. The finding of selective faculty in parasites at once sets the problem of host-selection as one of fundamental importance, by reason of its direct application in the practice of biological control. It is in this field that one has to look for explanations for many an obscure phenomenon such as superparasitism, multiparasitism and the like, which have a vital bearing on parasite-introductions.

Previous work in the line.—Though a large amount of scattered information on the problem of host-selection exists in literature, experimental investigations in this field have been very few. Salt (1935) has studied this aspect in great detail in respect of the polyphagous egg-parasite, *Trichogramma evanescens* Westw. Similar work on the Chalcid, *Microplectron fuscipennis* (Zett.), parasitising the Tenthredinid, *Diprion*, was published by Ullyet (1936). Lloyd (1938) has published his studies on the gipsy-moth egg-parasite *Ooencyrtus kuvanæ* Howard. Salt and Lloyd have shown that these egg-parasites are able to distinguish between parasitised and unparasitised hosts and partially refrain from ovipositing in the former. The most recent publication on the subject (Lloyd, 1940) demonstrates this capacity in the Ichneumonid genera, *Diadromus* and *Angitia*, parasitic on *Plutella maculipennis* (Curt.). These studies are obviously too few to admit of generalisation. Further, apart from a brief study of *Apanteles plutellæ* Kurd. by Lloyd (1940), no Braconid seems to have received serious attention in this direction. The aim of the present work, therefore, is to record the results of investigations on the selective faculties of the Braconid *Spathius critolaus* Nixon.



Temperature-Humidity curve Oct. 1939-Oct. 1940
Humidity

Scope of the present studies.—The present investigations have been designed to examine two different aspects of the problem, firstly, to test the tropic responses of the parasite to sensory impressions awakened by the host relative to its shape, size, texture and odour. In the second place an attempt is made to determine the factors governing the incidence of superparasitism and the general inter-actions of host-parasite populations.

General biology and oviposition habits.—*Spathius critolaus* Nixon is a primary, ectophagous larval parasite of the stem-boring weevil, *Pempherulus affinis* (Fst.), a major pest of cotton in South India. The biology and habits of the parasite have been already reported in some detail (Krishna Ayyar, 1940); a brief outline of which is given here. The species shows a preference for mature host-grubs and occasionally accepts medium-sized grubs (*i.e.*, third and fourth instars), but only very rarely young grubs. It ordinarily lays one egg per host, sometimes more. Besides *Pempherulus*, its hosts in nature include the amaranthus stem-boring weevil, *Hypolixus truncatulus*, the Bostrychid borer of cotton stalks, *Sinoxylon sudanicum* and the Buprestid stem borer of *Sesbania*, *Sphenoptera arachides*. The parasite occasionally attacks *Pempherulus* in a variety of plants besides cotton, such as *Triumfetta rhomboidea* and *Corchorus olitorius* (Tiliaceæ), *Sida acuta*, *Pavonia zeylanica*, *Malvastrum coromandelianum*, *Hibiscus vitifolius*, *H. esculentus* and *H. ficulnens* (Malvaceæ). *Spathius critolaus* is the most important species in the weevil's parasite-complex. It is the only species parasitising the first generation of the pest. Besides, it is amenable to mass multiplication on its alternate hosts. If properly manipulated, it promises to be a significant factor in weevil control. A detailed study of its behaviour was, therefore, undertaken as a preliminary to its utilisation in biological control.

Method of exposure of hosts to the action of the female parasite.—The female parasites used in these experiments were reared in the laboratory and had not oviposited previously. Unless otherwise stated, they were used for a period not exceeding 12 days after the pre-oviposition period. A varying number of females has been utilised for each test with a minimum of three. As far as possible, the conditions provided for each set of trials were made almost identical. In all trials where comparison of results is needed, experiments with one of the natural hosts of the parasite have been included as control. Since the host is a stem-borer and since the parasites accept only "covered" hosts as distinguished from naked or exposed hosts, unparasitised host stages were secured and lodged in artificial cells in stems of plants of uniform thickness or in gelatine capsules as described in a previous paper (Krishna Ayyar, 1940). The female parasites were confined in tubes (6″ x 1″) with a given number of hosts for a fixed time. The temperature-humidity conditions during the period of experiments are shown in the curve on the opposite page. Wherever possible,

behaviour of the parasite in the laboratory has been compared with observations in the field.

EXPERIMENTS TO TEST SENSORY IMPRESSIONS

Discrimination between true and false hosts.—Very nearly 200 experiments were carried out with various kinds of hosts to see whether the insect is able to select the true from false hosts. Table I below furnishes details of the trials together with results obtained. In these experiments all hosts were enclosed in gelatine capsules, except in the case of those presented naked.

TABLE I. *Capacity of the parasite to discriminate between true and false hosts*

Host and method of supply	No. of trials	No. of cases of oviposition
Pieces of pith of the size of *Pempherulus* grubs in gelatine capsules	10	Nil
- do - of the size of grub of *Hypolixus truncatulus*	10	Nil
Hypolixus grubs	76	31
Sinoxylon sudanicum grubs	10	7
Potter-wasp grubs	6	1
House-fly maggots	6	Nil
Cattle manure beetle grubs (Melolonthids)	6	Nil
Honey-bee larvæ	27	Nil
Chilo simplex caterpillars	18	Nil
Fruitfly maggots	10	Nil
Zizyphus fruit-borer pupæ	3	Nil
Zizyphus fruit-borer caterpillars	3	Nil
Sphenoptera gossypii grubs	9	4
House-fly pupæ	10	1
Ant cocoons	6	Nil
Naked ant pupæ	6	Nil
Alcides affaber pupæ	16	Nil
Alcides early grubs	16	Nil
Alcides mature grubs	16	4
Apion grubs	6	3
Alcides grubs naked—not in capsules	16	Nil
Pempherulus grubs ,, ,,	16	Nil
Hypolixus grubs ,, ,,	16	Nil
Sphenoptera grubs ,, ,,	6	Nil

It will be noticed that oviposition occurred, though varying in extent, on all coleopterous stem-borer grubs such as *Alcides*, *Apion*, *Hypolixus* (Curculionidæ), *Sinoxylon* (Bostrychidæ) and *Sphenoptera* (Buprestidæ). Other coleopterous grubs like Melolonthids were not oviposited upon. False hosts like *Chilo simplex* caterpillars, *Zizyphus* fruit-borer caterpillars, honey bee larvæ and pupæ, ant cocoons, fly maggots, etc., were not accepted for oviposition. Foreign inanimate bodies like pith pieces were

not touched at all. Two cases of abnormal oviposition were observed once on potterwasp grubs and again on house-fly pupæ. These cases have to be accounted for as due to an " error of instinct " rather than due to any deliberate choice. Barring these two abnormal instances, the parasite has displayed in the great majority of trials a capacity to reject all false hosts and choose only such as are closely akin to its true and normal hosts. It may also be evident that the species pays no attention to exposed or naked hosts even if they happen to be its true hosts.

Shape.—The experiments described above serve to shed some light on the shape of the host as a factor influencing acceptance or rejection. False hosts like pieces of pith modelled in the shape of its true hosts were rejected. Curculionid grubs which are more or less cylindrical differ very much in shape from the flat-headed borers like *Sphenoptera* (Buprestidæ), while both these forms differ widely from Bostrychid grubs like those of *Sinoxylon*. Yet all these are seen to be oviposited upon. It is, therefore, evident that shape by itself is not a deciding factor in the choice of the host.

TABLE II. *Oviposition on false hosts smeared with body fluids of natural hosts*

Host and method of supply	No. of trials	No. of cases of oviposition
Ant grubs smeared with *Pempherulus* fluid in capsules	12	Nil
Ant grubs smeared with *Hypolixus* fluid in ,,	12	,,
Pith pieces smeared with *Pempherulus* fluid in ,,	12	,,
Cattle manure grubs smeared with *Pempherulus* fluid in ,,	12	,,
Fly maggots smeared with *Pempherulus* fluid in ,,	12	,,
Chilo simplex caterpillars smeared in *Pempherulus* fluid in ,,	12	,,
Pempherulus grubs in ,,	12	6

Odour tests.—It is well known that the odour emanating from a plant or an insect host forms the basis of an initial attraction of many insects for oviposition and feeding. Since the parasite does not accept exposed hosts it may be conceded that the trials in odour mainly concern that of the covering. Nearly 200 trials with various kinds of hosts smeared with or soaked in the body fluids of its natural hosts and provided in gelatine capsules and in a variety of plant stems were made as detailed in Tables II and III. In the case of gelatine capsules minute pin holes were made in them for facilitating the odour of the enclosed host to emanate.

It may be seen from these tables that pith pieces, ant grubs cattle manure grubs, fly maggots, etc., even though soaked in the blood of true hosts, were always rejected. It is also evident that true

hosts supplied in various stems including hollow reeds, *cholam* (*Sorghum*) stems are oviposited upon. These indicate that odour either of the host or of the plant is not by itself a decisive factor and that the selection is probably to a great extent governed by the contact stimulus between the ovipositor of the parasite and the host body.

TABLE III. *Oviposition on hosts supplied in different plants*

Host and method of supply	No. of trials	No. of cases of oviposition
Hypolixus grubs in cotton stems	9	5
,, in hollow reeds	9	6
,, ,, amaranthus stem	9	5
,, ,, cholam stem	9	2
Pempherulus ,, amaranthus stem	25	9
,, ,, cotton stems	12	7
,, ,, *Sida spinosa*	9	3
,, ,, *Corchorus olitorius* stem	9	4
,, ,, *Malvastrum* stem	9	3
Sinoxylon ,, cotton stem	9	5
,, ,, amaranthus stem	9	3
,, ,, cholam stem	9	1

Trials on texture and form of covering.—Prior to oviposition, the parasite female explores the region carefully by its olfactory and tactile sense organs, such as antennæ, tarsi and sheaths of the ovipositor. The examination is probably concerned with location and testing the suitability of the texture of the host and of the covering provided. Results of trials carried out with different kinds and forms of wrappings are detailed in the Table IV :

TABLE IV. *Oviposition on hosts under different kinds of wrappings*

Host and method of supply	No. of trials	No. of cases of oviposition
Hypolixus grubs rolled up in war printing paper	8	1
,, ,, black paper	8	2
,, ,, thick white paper	12	2
,, ,, red blotting paper	8	3
,, ,, tin foil (cigarette case)	8	Nil
,, ,, tissue paper	8	Nil
,, ,, reeds	8	3

The results set forth in Table IV prove that the texture and the form of wrappings do not govern oviposition to any appreciable extent. Oviposition was secured on *Hypolixus* grubs in all the different kinds of envelopes such as brown paper, blotting paper, reeds, etc., except in the case of tin foil and tissue paper. The parasite failed to oviposit in tin

foil probably due to its impenetrable nature for the ovipositor. In regard to tissue paper, it may be that the covering provided is too thin and transparent. Being polyphagous, the parasite appears to reconcile itself to a variety of envelopes of different textures and forms. On the question of the texture of the host body itself, the parasite appears to be indifferent, since eggs are seen to be deposited on both the soft parts as well as hard chitinised parts like head capsule.

Specific stadium and size of host preferred.—Preliminary studies indicated that the size of the host has considerable bearing on the choice. Over 700 trials with all its natural hosts presented in a wide range of sizes were conducted in individual cages to test the importance of this factor in the matter of selection. Table V records details and results of these tests.

TABLE V. *Oviposition on hosts of different stadia and sizes*

Host and method of supply		No. of trials	No. of cases of oviposition
Hypolixus	pupæ in amaranthus stems	12	Nil
,,	prepupæ in ,,	24	1
,,	II instar grubs in ,,	165	34
,,	III ,, ,,	165	36
,,	IV ,, ,,	165	29
,,	V ,, ,,	165	20
Pempherulus	early grubs in cotton stems	12	1
,,	medium grubs ,,	12	3
,,	mature grubs ,,	12	9
,,	pupa ,,	12	Nil
,,	prepupæ ,,	12	1
Sinoxylon	early grubs in cotton stems	12	2
,,	mature grubs ,,	12	8
,,	pupæ ,,	12	Nil

The data recorded in Table V indicate a distinct perference for a particular stadium in the development of the host grubs. Pupæ are totally rejected. Prepupæ are also not readily accepted and only an occasional oviposition is seen. In *Pempherulus* and *Sinoxylon,* early stages of grubs, which are too small to afford sufficient food for the offspring are less preferred than full-grown ones. In the case of *Hypolixus* grubs, which are comparatively large-sized, the later instar grubs such as IV and V are less acceptable than the earlier small-sized ones. Besides, large-sized grubs of this host are only partially paralysed by the sting of the ovipositor. Anyway, the preference for mature grubs of *Pempherulus* and *Sinoxylon* is clearly evident. This discrimination is probably based on the optimum quantity of nutrition available for the sustenance of the parasite larva. In other words, the choice is restricted not only to a particular stadium but also to some extent to an appropriate size of the host.

Trials with parasitised, dead, diseased and mangled hosts.—Table VI presents results obtained from about 250 separate experiments on diseased and dead hosts. All hosts were supplied in amaranthus stems.

TABLE VI. *Oviposition on parasitised, injured and dead hosts*

Host and method of supply	No. of trials	No. of cases of oviposition
Hypolixus grubs containing a parasite egg presented to same female	30	4
,, to different female	24	4
,, grubs containing first stage parasite larva offered to same female	29	1
,, grubs containing first stage parasite larva offered to different female	21	1
,, grubs containing second stage parasite larva offered to same female	18	Nil
,, grubs containing second stage parasite larva offered to different female	18	Nil
Paralysed *Hypolixus* grubs with egg removed	18	2
Hypolixus injured slightly (pricked by a needle)	18	8
,, killed in boiling water (finally passed through cold water)	24	Nil
,, crushed but active	23	2
,, (blackened and diseased grubs)	18	Nil

It may be noted that host grubs already containing a parasite egg are occasionally accepted by the same female and are to a slightly greater extent acceptable to a different female. Host grubs having a first stage parasite larva are only very rarely accepted. Hosts possessing more advanced parasite larvæ are not accepted at all. Paralysed stages of hosts are sometimes acceptable for oviposition ; dead and diseased hosts are entirely rejected. Injured host stages are generally untouched but are acceptable when the injury is slight and the grubs are active. It is evident from the above, as pointed out by Salt (1934), that the ovipositing female is, in a way, able to discriminate between a parasitised host and a non-parasitised one, parasitised by herself and by others, as well as inactive, dead, diseased and injured ones.

In summing up the results of these experiments, it is evident that tropic responses influencing the attraction or rejection of a host seem to be highly complex and difficult of analysis. It looks as if no single factor, by itself, is responsible for the observed effect. Curculionid stem-boring grubs and allied coleopterous grubs with similar habits are more readily accepted as hosts than others. Objects of the same size, shape or odour as the hosts are generally rejected. It would appear that the shape, odour and texture of the host are of only minor importance in their acceptance for oviposition. Size of the host within certain limits seems to exercise some appreciable influence in the choice of the prey. The final selection

by the parasite, however, appears to be governed by the presence of an active, stem-boring curculionid or other allied coleopterous larvæ of similar habits (within a definite range of size) beneath a covering.

Discrimination experiments in oviposition and progeny distribution

A series of experiments was carried out with this species to study the powers of the female parasite to distinguish between unaffected healthy hosts and those already parasitised. Experimental data are presented to elucidate the factors governing the incidence of super-parasitism, mortality, restraint, etc., relative to the number and nature of insect hosts and their various plant associations. The technique of presenting the host to the parasite is the same as described in the earlier paragraphs.

(1) *Healthy unparasitised host-grubs and newly parasitised grubs but with egg removed.*—A regular supply of newly parasitised grubs was obtained by exposing healthy grubs enclosed in stems to the female parasite. The parasitised grubs were examined and the eggs found laid were all removed leaving the stem with only the paralysed host grub. This was presented to the female parasite along with a fresh unparasitised host grub. Nearly seventy experiments with a set of ten females were made and the results obtained show that 52 eggs were laid on fresh grubs, *i.e.*, 74.3% and 5 eggs on parasitised grubs, *i.e.*, 7.1%. The results demonstrate clearly that the female parasite is able to discriminate between fresh grubs and parasitised grubs, even though the eggs are removed. It may also be seen that paralysed grubs are not totally rejected, though a high degree of preference is shown to fresh hosts.

(2) *Healthy unparasitised hosts and hosts with various developmental stages of parasite.*—

(*a*) *Healthy host grub and parasitised grub with one egg.*—In this category 56 trials were made with a set of 12 females. The results obtained show that 38 eggs were laid on fresh grubs and a single egg was laid on host grub with an egg already laid on it. In the case of host grubs parasitised with one egg offered with fresh grubs, a pronounced discrimination was shown in that only 1.78 eggs per 100 trials were observed as against 67.85 eggs on fresh grubs.

(*b*) *A parasitised grub with one egg and one with first stage larva.*—A total of 33 trials in this category was made with a set of 7 females. The results show that one egg was laid on a host, with an egg already, and no oviposition at all on hosts with a first stage parasite larva.

A pronounced avoidance of hosts with parasite eggs is noted as seen from 3.0 eggs per 100 trials and a total rejection of host grubs with first stage larva is evident. It is also clear that considerable restraint is

exercised by the females in refraining from oviposition. Trials with hosts having more advanced parasite stages (such as second and third instar larvæ) were made with similar results, namely total rejection. The results are the same whether the parasitized stages are offered to the same female or different females.

These experiments clearly bring out the following points. The parasitized hosts are generally avoided when a choice is offered. When no choice is offered the females exercise restraint to a surprising degree and reject hosts containing even younger parasite larvæ. The selective powers in the species are very marked.

Superparasitism in relation to the number and nature of hosts

It is well known that there exists some relationship between the rate of oviposition of a parasite female and the density of host population. It has also been noted that superparasitism under certain conditions occurs more frequently than under others. Experiments were carried out to elucidate the relation between incidence of superparasitism with the nature and number of hosts and results are set forth in Table VII.

TABLE VII. *Influence of nature and number of hosts on the incidence of superparasitism*

Stage of *Pempherulus* supplied	No. of hosts supplied per female	No. of trials	No. of eggs laid	Percentage of superparasitism	No. of ♀♀ tried
Pupa	1	46	Nil	Nil	6
Prepupa	1	46	2	,,	6
Mature grub	1	59	56	22.03	6
,,	2	69	65	27.53	6
,,	3	69	69	17.39	6
,,	4	104	50	4.80	6

An examination of the above table confirms the results of previous trials that pupæ are always rejected. Prepupæ are also avoided but under certain circumstances an egg may occasionally be laid, (2 cases of oviposition in 46 trials). The results obtained in experiments with an increasing number of mature host grubs are interesting. A gradual increase of oviposition occurs from 56 in trials with one host up to 69 in trials with 3 hosts per female. It appears, therefore, that the limit of maximum oviposition is reached with the optimum of three hosts. But the figures indicating the percentage of superparasitism are more illuminating. In the presence of only one or two hosts, the percentage of superparasitism is as high as 22.03 and 27.53, but when 3 or 4 hosts were presented, the incidence of

superparasitism fell to 17.39 and 4.80 ; these figures are very significant. It may be inferred from these trials that superparasitism, to some extent, decreases when number of hosts available increases from two to four.

Superparasitism in relation to the food-plants of the weevil

Pempherulus is oligophagous and among its natural food-plants may be counted a large number of malvaceous and some tiliaceous plants. Painter (1936) states that food-plants of hosts influence the incidence and effectiveness of insect parasitism through their effect on death-rate and fecundity. Taylor (1937) quotes Picard and Rabaud (relative to *Heliothis armigera*) that parasites in some cases are not so much attracted by specific insect hosts as by the plant on which they live and feed. This also appears to be true in the case of another parasite of *Pempherulus*, namely, *S. labdacus* Nixon, which has been so far observed to occur only in association with the plant *Triumfetta rhomboidea*. The species under study, on the other hand, parasitizes the host in different food-plants. The influence of different food-plants on its incidence, oviposition, superparasitism, mortality, etc., in comparison with its primary host (cotton) was investigated. In this series, the plants tested included both the natural food-plants of the weevil as also several others. Among the latter were included some plants with unusual characteristics and possessing acrid juices, gummy exudations or having a poisonous composition.

In all these trials, as previously described, the host (*Pempherulus*) was lodged in the particular plant and presented to the females together with a host in cotton, so as to afford a choice and thus eliminate coercion. In the case of tests with leaves or paper, the host was rolled up in the same. The results are recorded separately for each plant host (*vide* Tables VIII & IX).

The data obtained from these experiments appear to be very difficult of interpretation ; some important conclusions can yet be deduced from them. It is seen that oviposition occurs in hosts enclosed in both their natural and other food-plants, save a few definitely poisonous plants such as *Calotropis, Datura* and tobacco. Among the weevil's natural host-plants, some are more acceptable and others less than its primary food-plant, *viz.*, cotton, as measured by the percentage of superparasitism. It is known that the female parasite ordinarily avoids ovipositing on an already parasitized host. Hence if superparasitism takes place in one plant species, it may be presumed that the other plant offered as choice is less acceptable. In other words the greater the superparasitism in one species the less the attraction exercised by the other plant which is available as choice. In the case of all trials with unnatural (non-host) plants there is a greater percentage of superparasitism in cotton (except in

paper covering), showing thereby that the female parasite prefers to oviposit on an already parasitized host in cotton to a fresh host or a similar host in the non-host plant. Thus, the food-plant of the host is seen to influence the oviposition and superparasitism to some extent, though the host insect inside is the greater deciding factor. Whether this discriminating faculty displayed by the parasite between host plants and non-host plants can be taken as a criterion to test and distinguish the natural host from others, it is too premature to decide from the data available. The suggestion contained in the statement, if found to be true and applicable in other cases, will prove to be of far-reaching significance.

TABLE VIII. *Incidence of parasite on host, supplied simultaneously in cotton and other natural host plants*

Plant species	Number of trials	Percentage of superparasitism	
		in cotton	in other sp.
Malvastrum coromandelianum	42	..	2.38
Triumfetta rhomboidea	52	..	1.92
Hibiscus vitifolius	45	..	2.22
Sida spinosa	42	..	..
Hibiscus ficulneus	46	..	..
Sida rhomboidea	42	4.76	2.38
Urena sinuata	48	..	..
Corchorus olitorius	20	..	..
C. acutangulus	20	5.0	..
Sida acuta	20	5.0	..
Pavonia zeylonica	20	15.0	15.0
Karunganni cotton	12	8.33	4.6

MORTALITY IN SUPERPARASITISM

Normally a single egg is laid on one host, but on rare occasions as many as six or seven eggs are laid on some large-sized host grubs. The maximum number of adults emerging from a single host has never exceeded six. Ordinarily the emergences from superparasitism are very much limited and form only a fraction of the number of eggs deposited. Table X furnishes data on superparasitism on hosts in association with various species of plant.

The data do not indicate any appreciable difference in the emergences between natural host-plants and others. These, however, demonstrate that superparasitism is not accompanied by a development of the entire progeny.

SUPERPARASITISM AND DELAYED FACILITIES FOR OVIPOSITION

In order to test whether superparasitism is influenced by irregularity in finding oviposition-facilities due to scarcity of hosts, adverse weather

conditions, etc., the following series of experiments were carried out with delayed facilities for oviposition. A sufficient number of females was kept isolated on emergence individually in tubes, fed, mated and kept for varying periods up to a maximum of 35 days, without providing hosts for oviposition. Hosts were provided in the usual manner after the lapse of a definite number of days and the results are recorded in Table XI.

TABLE IX. *Incidence of parasite on host, supplied simultaneously in cotton and unnatural (non-host)-plants**

Plant species and paper	Number of trials	Percentage of superparasitism	
		in cotton	in other sp.
Corchorus trilocularis	42	..	..
Triumfetta rotundifolia	40	2.50	..
Azadirachta indica	31	2.58	1.61
Paper	30	3.22	6.66
Tamarindus indica	33	..	..
Pomegranate	31	3.33	..
Murraya königi	30	16.61	13.33
Mangifera indica	30	20.0	16.61
Pongamia glabra	21	..	..
Peltoforum ferruginium	21	9.52	4.76
Acacia arabica	21	..	..
Hibiscus rosa-sinensis	20	10.0	5.0
Thespesia populnea	20	10.0	..
Andropogon sorghum	20	..	..
Opuntia dilenii	20	35.0	5.0
Glyceridia maculata	18	33.3	27.7
Calotropis gigantia (leaf)	18	5.55	5.55
– do – (stem)	17	11.76	..
Ficus religiosa	15	13.33	..
Thevetia	19	42.0	10.5
Tobacco leaf	14	14.28	..
Agave americana	15	..	..
Datura (leaf)	15	13.3	..
—do— (stem)	15	26.66	..

Oviposition commences only on the third day. The data on superparasitism show a maximum average of 50% on the 4th and 8th days, with varying fluctuations up to 12 days. The maximum of oviposition was obtained with females 4 and 8 days old. There was no oviposition after 31 days. The egg-laying capacity is not materially increased by prevention of oviposition. There seems to be a maximum number of eggs which develop in the ovaries and this is reached within about 8 days. No further increase occurs thereafter.

* In all these cases the total number of eggs laid varied very much and in certain cases the number of eggs laid in non-host plants was (paradoxical as it might look) far in excess of those laid in cotton.

CONDITION OF THE OVARIES WITH REFERENCE TO AGE AND RESTRAINT

The following experiment was carried out to see whether accumulation of eggs in the ovary occurred due to exercise of restraint by the females in the absence of suitable hosts for oviposition. A series of females on emergence were mated and kept isolated for periods ranging from 1 to 21 days without providing hosts. Dissections of gonads were made on different dates and examined for the number and nature of eggs present. The Table XII provides the average of several observations.

TABLE X. *Superparasitism and survival of parasite on hosts supplied in different plants*

Plants enclosing host	No. of cases of superparasitism	Total No. of eggs laid	Percentage of emergence
	A. Natural food-plants		
Cambodia cotton	106	315	46.98
Triumfetta rhomboidea	5	15	66.66
Pavonia zeylanica	5	14	50.00
Sida acuta	6	16	50.00
	B. Non-host plants		
Acacia arabica	3	6	Nil
Mangifera indica	3	10	50.00
Enterolobium saman	4	11	63.63
Thespesia (leaf)	1	4	25.00
Glyceridia maculata	5	15	40.00
Nerium odorum	2	6	50.00
—do— (leaf)	1	2	Nil
Thevetia	1	4	50.00
Azadirachta indica	6	14	14.28
Hibiscus rosa-sinensis	1	2	50.00
Mulberry	2	4	Nil

These data more or less support the observations recorded in the previous experiment. It is clear that age and restraint have not produced any marked accumulation of developed eggs in the ovaries.

Superparasitism with reference to (1) *light and darkness and* (2) *day and night.*—Data on the oviposition-behaviour of the species in light and darkness as also in day and night are recorded in Table XIII. In the case of the latter experiment, the hosts were provided between 6 p.m. and 6 a.m. for night trials and between 6 a.m. to 6 p.m. for day trials.

The data presented in the above table do not show any striking differences in oviposition or superparasitism under the different conditions provided. There occurs a slight increase in superparasitism at night, as compared with that during the day time.

TABLE XI. *Superparasitism under delayed condition of supply of hosts*

Age of female from emergence before access to host	No. of females tried	Percent super-parasitism	Average no. of eggs laid per female
1 day old	7	Nil	Nil
2 days ,,	8	,,	,,
3 ,, ,,	18	5.55	0.22
4 ,, ,,	5	50.00	1.50
5 ,, ,,	5	Nil	0.60
6 ,, ,,	12	16.66	0.50
7 ,, ,,	16	18.75	0.93
8 ,, ,,	12	50.00	1.33
9 ,, ,,	4	25.00	0.50
10 ,, ,,	6	14.28	0.85
12 ,, ,,	9	22.00	0.66
16 ,, ,,	4	Nil	Nil
17 ,, ,,	4	,,	0.25
23 ,, ,,	6	,,	0.33
31 ,, ,,	6	,,	0.16
34 ,, ,,	6	,,	Nil
35 ,, ,,	6	,,	,,

TABLE XII. *Number and nature of eggs laid with reference to age of parasite*

Age of female from emergence in days	No. of fully developed eggs	No. of eggs partially developed	No. of eggs poorly developed
1	Nil	Nil	1
2	,,	2	1
3	4	1	1
4	4	2	1
5	4	3	2
6	5	2	3
7	7	3	—
8	7	3	—

The observations were not continued after the 8th day, since, from the previous experiment, the maximum oviposition was seen to be attained by this period.

TABLE XIII. *Oviposition in light and darkness and during day and night*

	Light	Darkness	Day	Night
Number of trials	84	84	66	66
Number of females tried	14	14	6	6
Number of ovipositions	17	13	12	18
Total eggs laid	24	25	19	23
No. of cases of superparasitism	3	5	4	3
Average No. of eggs per female	1.71	1.78	3.16	3.83

Summary and Conclusions

The present investigation was carried out in two parts; the first of which is concerned with the determination of the nature of the response of the parasite to the sensory impressions produced by such stimuli as shape, texture, odour, movement, etc., of the host. It has been demonstrated that all these factors operate not singly but in combination to render the host suitable for acceptance and that no single factor by itself can account for the resulting behaviour of the parasite. Among these, however, size and movement seem to exercise a marked degree of stimulus to initiate the observed reflexes.

The experiments comprising the second part have served to demonstrate that selection of host is determined by the quantitative and qualitative complexes among the characters of the host. The choice of the parasite, in general, falls on the host which is the most suitable, *i.e.*, the nearest approach in respect of a combination of characters to the natural host. In particular, these experiments have revealed the following responses in the oviposition behaviour of the parasite :—

The parasite normally prefers only the advanced grub stages beneath a covering, as hosts. Prepupæ and pupæ are rejected ; the former may rarely be oviposited upon but the pupæ are never acceptable at all. Early instar grubs are not unacceptable. The species is able to discriminate between parasitised and unparasitised hosts. When parasitised hosts only are offered, considerable restraint in oviposition occurs. Host grubs containing eggs were occasionally accepted and those with first instar larvæ were usually rejected when unparasitised hosts are available. There is a gradation in degree of acceptance of these even under stress of circumstances. Superparasitism is not of infrequent occurrence and is probably, to some extent, influenced by irregularity in the availability of hosts. It is almost always accompanied by a partial survival. Mortality in supernumerary larvæ was due more to competition for food and other similar reasons and not so much due to fight. Superparasitism is influenced by the number and nature of hosts available. Absence of facilities for oviposition did not cause any unusual accumulation of eggs in ovaries. In the laboratory, oviposition takes place on hosts enclosed in its natural food-plants, as well as others, save some definitely poisonous plants. Superparasitism appears to be forced on hosts lodged in natural food-plants, when the parasite is confronted simultaneously with hosts in non-host plants. No case of multiparasitism in nature has been observed. In the laboratory, parasitised hosts by this species were rejected by other species of parasites of the weevil. These findings are of fundamental importance and utilisation in biological control of the weevil.

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GENETIC AND SYSTEMATIC STUDIES ON INDIAN DROSOPHILA

I. Description of two new species of *Drosophila*: Life-history and preliminary studies on the genetic constitution of *Drosophila emulata*, sp. nov.

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(*Communicated by D. Mukerji*)

The studies on the genetic structure of free-living *Drosophila* species initiated by Tschetwerikoff (1926) and dveloped by Dubinin (1934), Sturtevant and Dozhansky (1936), Dobzhansky (1939) and their co-workers, have opened a new field of research on the problem of organic evolution. Genetical studies in reference to the question of species formation have been neglected in India. With a view to exploring the possibilities of genetic research on these flies in India, the present authors started collecting the wild species of *Drosophila* in Calcutta and encountered two new species, which were the subject of enquiry for the mutation of genes. In this paper descriptions of these two new species, together with an account of the life-history of one of them (*D. emulata*, sp. nov.), are given. Descriptions and mode of inheritance of certain mutations obtained in a heterozygous condition in the wild population of this species are also given in brief.

Material and Technique

In their larval stages most species of *Drosophila* feed on fruit or fungi, or are leaf-miners. It is easy to attract the commoner species to over-ripe bananas kept in fruit stores. The flies thus caught were brought to the laboratory and etherized. Males and females were first separated and a pair were transferred to separate small glass vials, containing standard maize-meal-agar medium as per technique described in *Drosophila Information Service*, Vol. 6. Pure cultures of both the species were thus separately raised and the systematic descriptions given here are based on specimens from such stock cultures. The data on the ratios of different bristles and wing-venation indices were calculated from measurements of the different structures selected from a large number of individual of different stock cultures of the same species. The range of variation of the wing-vein indices is also given. The measurements of the size of the flies and their

wings were made from mature flies (3-4 days old) bred on the standard medium at a constant temperature of 26°±2° C. Living stocks of wild and mutant flies of the two species described in this paper are being continuously kept on standard culture medium in the Zoological Laboratory of the Calcutta University.

I. SYSTEMATIC DESCRIPTION

The only endemic species of *Drosophila* so far recorded from India is *D. prashadi* Brunetti (1923), the type-locality of which is Calcutta. Six other species reported from India are more or less cosmopolitan in distribution : *D. melanogaster* Meigen, *D. ananassæ* Doleschall, *D. montium* de Meijere, *D. tristipennis* Duda, *D. bipectinata* Duda and *D. repleta* Wallaston.

The first four species were collected from Nungambaukam, Madras (Sturtevant, 1927). Of the remaining two species, *D. bipectinata*, the type specimen of which is in the Hungarian National Museum, was described by Duda (1923), and its type-locality is Darjeeling. *D. repleta* was recorded from Calcutta by Bezzi (Sturtevant, 1921). It may be noted here that *D. melanogaster* and *D. repleta* are cosmopolitan in the true sense, whereas *D. ananassæ* and *D. montium* appear to be limited to the oriental region. The former has been recorded from Java, Formosa, Sumatra, New-Guinea and India and the latter from Java, Formosa, India and West Indies.

Drosophila brunettii, sp. nov.

Male.—Arista with four branches above and three below, excluding the bifurcated terminal part of the main axis. Antennæ light brownish-yellow, the third joint grey. Front about one-third the width of the head, wider above, yellow. Second orbital bristle about one-half of the size of the other two. Second oral bristle nearly as long as the first. Face pale yellow. Cheeks extremely pale yellow. Acrostichal hairs in the front of the anterior dorso-central bristles in eight rows; no prescutellars. Mesonotum and scutellum pale brownish-yellow. Pleuræ and legs pale yellow. Preapical bristles on the first leg, apical and preapicals on the second leg, preapicals on the third. Wings clear. Costal index 1.5; fourth vein index 2.4; 5x index 1.9; 4c index 1.5. Length of the body and wing 2.0 mm.

Female.—Length of the body and wing 2.2 mm.

Drosophila emulata, sp. nov.

Male.—Arista with five branches above and three below, excluding the terminal part of the main axis which is bifurcated.

Antennæ pale brown, third joint grey. Front about one-half the width of the head, wider above. Second orbital bristle about one-half the size of the other two. Second oral bristle as long as the first. Face pale brown. Cheeks extremely pale yellow. Acrostichal hairs in eight rows. Mesonotum and scutellum shining reddish-brown. Pleuræ and legs pale brown. Preapical bristle on the first leg, apicals and preapicals on the second and preapicals on the third. A comb-like row of about ten short curved black bristles on the inner distal surface of the basal tarsal segment of the first leg.

TABLE I. *Range of variation of the wing-vein indices in* D. brunettii, *sp. nov.*

No. of individuals	Costal index.	No. of individuals	4th vein index	No. of individuals	4c. index	No. of individuals	5x index
2	1.3	6	2.3	14	1.5	4	1.7
7	1.4	10	2.4	4	1.6	3	1.8
9	1.5	5	2.5	6	1.7	10	2.0
5	1.6	3	2.6	1	1.8	7	2.1
3	1.7						
Total	Average	Total	Average	Total	Average	Total	Average
26	1.5	24	2.4	25	1.5	24	1.9

Dorsal side of the last two segments of the abdomen shining black. Three other conspicuous black bands on the lower margin of the remaining segments, not extending to more than the middle of each segment. Wings clear. Costal index 2.5; 4th vein index 2.15; 4c index 1.1; 5x index 1.6. Length of the body 2.6 mm. Length of the wing 2.3 mm.

Female.—Length of the body 3.0 mm. Length of the wing 2.6 mm.

Range of variation of certain specific characters.—It is desirable to know the range of variation within the species of the different measurable characters used for taxonomic purposes. Sturtevant (1921) gives the range of variation in the number of dorsocentral bristles, wing-vein indices and number of rows of acrostichal hairs. Tables I and II show the variation in the wing-vein indices of *D. brunettii* and *D. emulata* respectively.*

Discussion.—*D. brunettii*, sp. nov. seems to be allied to *D. bipectinata*. The latter possesses two oblique combs of black stout bristles on the inner surface of first tarsal segment of the prothoracic leg but the former is

*In the description of the species referred to above we have given the average values of the different wing-vein indices.

without any such structure. The wing venation indices are about the same in both the species. Second orbital bristle is proportionately smaller in *D. bipectinata* than in *D. brunettii.*

D. emulata, sp. nov. resembles *D. melanogaster* Meigen closely. It differs from the latter, however, in the general colouration of the body, wing-venation indices and size. The body and the wings are of equal size in *D. melanogaster* that is 2.0 mm., but in *D. emulata* the wing is definitely smaller than the body both in the male and the female.

Table II. *Range of variation of the wing vein indices in* D. emulata, *sp. nov.*

No. of individuals	Costal index	No. of individuals	4th vein index	No. of individuals	4c index	No. of individuals	5x index
6 7 1 2	2.5 2.6 2.7 2.8	8 8	2.1 2.2	5 7 2 2	1.05 1.10 1.15 1.2	8 3 5	1.6 1.7 1.8
Total	Average	Total	Average	Total	Average	Total	Average
16	2.5	16	2.15	16	1.1	16	1.6

D. prashadi Brunetti was described from Calcutta and the two species described in this paper are quite distinct from it as explained below :

The description of *D. prashadi* as given by Brunetti, unfortunately refers mostly to generic characters and consequently applies to all the species of *Drosophila.* Two specific characters of taxonomic importance mentioned by him are (*i*) the number of bristles present on the arista and (*ii*) the bandings on the hind margins of the abdominal segments. The number of bristles on the arista, however, is shown by him to be a variable character and this might be anything from 2-4. Moreover he had two flies in the same collection which had 8 bristles on the arista, 5 above and 3 below. If we take into consideration these two exceptional flies the range of variation in the number comes to 2-8. As to the bandings of the abdomen he writes : " The hind margins of the abdominal segments are more or less narrowly black, the colours sometimes extending to the middle of the segments, sometimes hardly visible or quite absent". According to this description, the markings of the abdomen are also quite variable in *D. prashadi.* We have examined a large number of flies in our collection from the same locality to ascertain the range of variation of both these characters. In most of our flies the number of bristles on the arista is

quite constant. Occasionally, however, one gets one or two flies in which the number deviates from the normal, sometimes by one more or one less. But the range of variation never assumes such porportions as to be anywhere between 2 and 8. We have not been able to find any reference to the descriptions of any one of the hundreds of *Drosophila* species so far described, where such variation as given by Brunetti for *D. prashadi* is usual. The black banding on the abdominal segments is very conspicuous in *D. emulata* and extends to the middle of the segments but this is not so marked in *D. brunettii*. If one has got, without his knowledge, a mixed collection of these two species, he runs the risk of inferring that the bandings are more or less narrowly black, sometimes extending to the middle of the segments and sometimes are hardly visible, as was possibly done by Brunetti. This seems to be more likely, since *D. emulata* has 8 bristles on the antenna (5 above and 3 below) and if we take into consideration his two exceptional flies which have exactly this number, we are justified in concluding that he had a mixed collection of different species and did not distinguish them. An examination of the type specimens of this species in the Indian Museum, Calcutta, was also done but unfortunately the state of preservation was found to be so bad that important characters could not be studied. The description of the species given by him is applicable to all the common species of *Drosophila* found in Calcutta and it is difficult to say which of the species he really meant; it is, therefore, useless to retain the species created by him. We have called one of our species as *D. brunettii* after the name of Brunetti, since he was the first to describe an endemic species of *Drosophila* from India.

2. Life-History of *Drosophila emulata*

Eggs, larvæ and pupæ of all the species of *Drosophila*, although very similar, show certain variations, which afford excellent specific differences (Sturtevant, 1921; Kikkawa and Peng, 1938). Detailed study of these variations were not done during the present work. General descriptions of the various stages and references to literature can be obtained from Kikkawa and Peng's (1938) monograph on *Drosophila* species of Japan and adjacent localities.

The females usually lay eggs about 48 hours after emergence. The number of eggs laid by different females even of the same stock varies to a great extent. They continue to lay eggs for a month or more, at the rate of 50-60 per day, afterwards the rate of re-production gradually diminishes.

We have determined the duration of successive stages from the egg up to the emergence of the adult flies.

The following procedure was adopted in studying the life-history :

An ordinary glass-stoppered, wide-mouthed jar was taken and standard food medium was put into the cup-like depression of the hollow glass stopper. About 200 impregnated females were put in the jar and these were passed over to the glass stopper containing the food. Flies were allowed to lay eggs only for one hour and 30 minutes. Nearly 400 eggs were thus obtained within this period. The adults were then discarded and the eggs were allowed to hatch. The culture was regularly examined and the durations of various stages were noted. The whole life-history was worked out at a constant temperature of $26^\circ \pm 2^\circ C$.

The first larva came out 17 hrs. 15 mins. after the starting of the egg-laying and all the larvæ crawled out within 20 hrs. 30 mins. of the commencement of oviposition. The time which elapsed between the hatching of the first and the last larvæ is, therefore, 3 hrs. 15 mins. Had the rate of development or the growth-rate been the same in all the individual eggs, the difference in time between the first and the last larvæ to come out of the eggs, should not have exceeded 1 hr. 30 mins., that is, by a period of more than the age difference between the first and the last egg laid.

The first pupa was formed 94 hours after the first larva came out of the egg shell. All of them pupated within eight hours. We find here a discrepancy of 4 hrs. 45 mins., if we assume the rate of growth of all the larvæ to be uniform.

The first imago emerged from the pupal case 72 hrs. after pupation. The emergence of all the individuals was completed within 22 hrs.

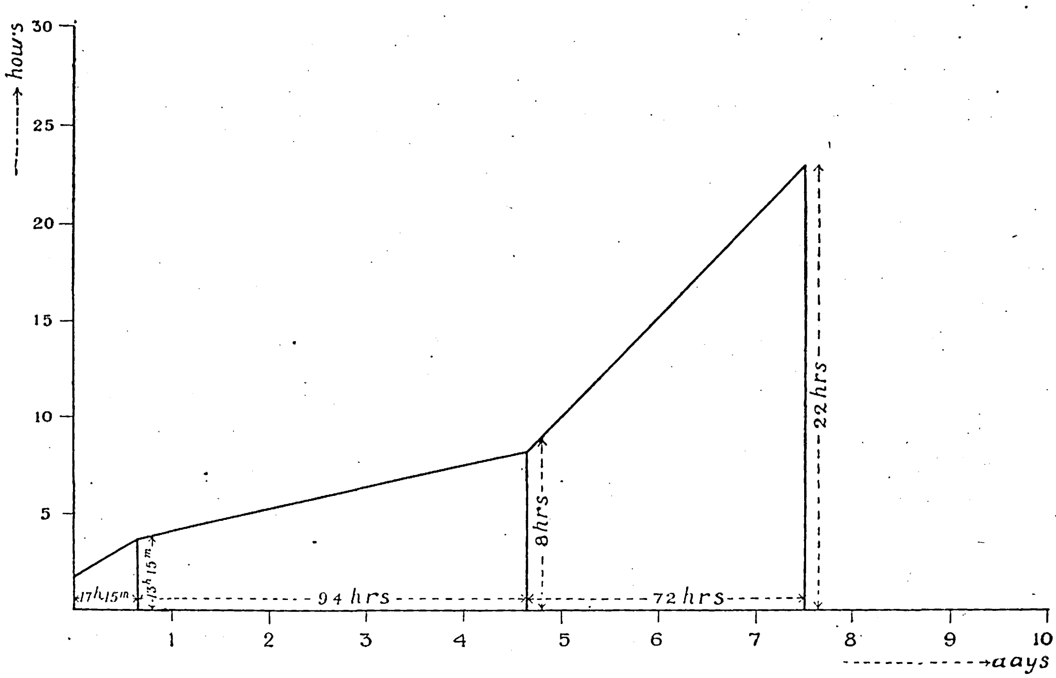
We started with an age difference of not more than 1 hr. 30 mins. between the first egg and last egg laid but at the end of the development we found the age difference between the first and last imago to be as high as 22 hrs. This is remarkable since this difference was obtained in a species in which the life-history is completed within such a short period.

The above results are graphically represented where the abscissa gives the time interval between the first appearances of successive stages and the ordinates stand for the duration of laying, hatching, pupation and emergence. From the graph it is obvious that the growth rate is not the same throughout. If the growth rates at the different stages varied uniformly we would, within limits of experimental error, get a straight line joining the tops of the ordinates. The pattern, however, shows that this is not the case. The variation in the growth rates at successive stages of the life-history is different. From the data given in the graph we can calculate the extreme growth rates at the various stages.

We do not know exactly which one of the eggs laid within the period of 1 hr. 30 mins. hatched out first. In an extreme case, therefore, it is possible that an egg laid at the end of the laying period might be the one which hatched out first. Therefore, the shortest possible period in which an egg can hatch is 17 hrs. 15 mins *minus* 1 hr. 30 mins., *viz.*, 15 hrs. 45 mins. Similarly the longest period is 17 hrs. 15 mins. *plus* 3 hrs. 15 mins., *viz.*, 20 hrs. 30 mins. The ratio of the two extreme growth rates for this stage is 20.5 hours: 15.75 hours or 1.0 : 0.77. Therefore the dispersion is

$$\frac{1.0-0.77}{\frac{1}{2}\,(1.77)} : 100 = 26\%$$

Similarly for the larval and pupal stages the dispersions are 11 % and 38 % respectively.



Thus it appears that the variation in growth-rate is the maximum in the pupal stage and minimum in the larval stage. Since all the eggs were under identical environmental conditions, we can only interpret our results by postulating variations in the genetic make-up of the eggs. These variations are probably due to a certain gene or genes which control the rate of growth. The longest period (94 hrs.) in the life-cycle intervenes at the larval stage. The larvæ have an independent existence and move about freely in search of food. If the environment had any significant role in our experiment, in causing variation in growth rates, we should expect the dispersion in the larval stage to be the maximum. On the

contrary we find it to be the lowest, being only 11 %. Evidently the genes which cause these variability in the rate of development at various stages must have acted during the intra-embryonic period and reaching its height in the pupal stage.

3. GENE MUTATION OBTAINED IN *DROSOPHILA EMULATA*

About 50 flies were trapped near a market in Ballygunge in Calcutta and 24 pair-matings were done in small glass vials. F_1 individuals were obtained from progeny in each vial and about 6 brother-sister matings were done for each family to obtain F_2. Flies of each generation were carefully examined for visible mutations. It is easy to see how a recessive autosomal mutation present in a hetrozygous condition in the wild population, can manifest themselves in F_2 by this process of enforced homozygosis through close inbreeding. No attempt was made, however, in this preliminary survey to determine quantitatively the frequency of mutated gene present in the wild sample. Three definite mutations and a probable fourth were obtained amongst the F_2 progeny. They are described below :

(*i*) '*garnet*'—An autosomal recessive mutation affecting the eye colour of the flies. The garnet eye-colour is much lighter and is very pronounced in the newly emerged flies. With the age of the flies the colour becomes darker, but it is always possible, with a little practice, to distinguish them from the wild type.

(*ii*) '*curved*'—An autosomal recessive mutation affecting the shape of the wing. Homozygous curved flies have the tip of their wings curved upwards instead of being flatly placed on the back.

(*iii*) '*posterior-cross-vein*'—An autosomal recessive mutation affecting wing venation. Homozygous 'posterior-cross-vein' flies have a small longitudinal branching of the posterior cross-vein in the 2nd posterior cell of the wing. The manifestation of this character is very irregular. Accurate data about its mode of inheritance are being worked out.

(*iv*) Several flies, both males and females, appeared in some of the F_2 vials with abnormal longitudinal veins. A few pair matings were done with these flies but none of them produced any offspring.

TABLE III

F_2 progeny obtained out of the F_1 between wild type and garnet flies

Wild type			Garnet			Wild garnet ratio
No. of males	No. of females	Total	No. of males	No. of females	Total	
246	281	527	85	92	176	2.99

Neither sex-linked recessive nor autosomal dominant mutation was found.

In Tables III, IV and V are given the number and kind of progeny obtained in course of determining the mode of inheritance of these mutations.

The F_2 ratios of wild and mutant flies (Tables III and IV) show that 'curved' and 'garnet' are two simple autosomal recessive genes. The ratios of the different types of F_2 progeny of curved-garnet cross are not much different from the expected 9 : 3 : 3 : 1 ratio, and therefore they are situated on two different chromosomes. We could not decide, as yet, whether posterior cross-vein is situated on the curved chromosome or on the garnet chromosome. It might be as well on a different chromosome altogether.

The results obtained show definitely that 'garnet' and 'curved' are two simple Mendelian autosomal recessive genes situated on two different chromosomes.

TABLE IV

F_2 progeny obtained out of the F_1 between wild type and curved flies

Wild type			Curved			Wild curved ratio
No. of males	No. of females	Total	No. of males	No. of females	Total	
95	87	182	22	26	48	3.79

TABLE V

F_2 progeny obtained out of the F_1 between curved and garnet flies

Wild type	Curved	Garnet	Curved and garnet
292	77	90	25

A more detailed study of the genetics of the two species described in this paper and also a quantitative genetical analysis of the wild population will be undertaken in winter, because culture of these flies can more easily be handled in large numbers during the colder months. Salivary gland chromosomes and other cytological studies of these species are in progress.

SUMMARY

Two new species of *Drosophila* are described from Calcutta; reasons are given to show why the only other species so far described from the same locality, cannot be retained.

"Indian J. Ent., **3** (2)"

Life-history of *D. emulata*, sp. nov. has been worked out in detail. In course of this investigation it was found that in spite of identical environmental conditions, under which the individual eggs, larvæ and pupæ were reared, they differed considerably in their rates of development. The existence of genes controlling the rates of development, acting at particular stages of the life-history, has been *presumed* to explain the differences in the rates of growth.

Three definite and a probable fourth autosomal recessive mutations have been found in heterozygous condition in 24 wild females caught near a market in Ballygunge, Calcutta.

ACKNOWLEDGMENTS

The authors are indebted to Dr. H. K. Mookerjee, D.Sc. (Lond.), Head of the department of Zoology, Calcutta University, for facilities and to Mr. D. Mukerji, Lecturer, Calcutta University, for constructive criticism.

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APHIDIDÆ AND SOME OTHER RHYNCHOTA FROM AFGHANISTAN

By GHULAMULLAH, *Assistant to the Imperial Entomologist, New Delhi.*

Very little is known about the Rhynchota fauna of Afghanistan; this is especially so about the Aphididæ. The only species of Aphididæ so far known from that country is *Pemphigus coccus* Buckt.*

The German Hindukush Expedition (*Deutsche im Hindukusch*) in 1935 made a general collection of insects, including about a dozen species only of Rhynchota from Afghanistan, which was described by Kiritshenko.†

Dr. Taskhir Ahmad, Assistant Entomologist, Imperial Agricultural Research Institute, New Delhi, during a tour of Afghanistan in June and July 1939, as a member of the Indian Agricultural Delegation, made a large collection of insects of all orders. The specimens of Rhynchota were kindly placed by him at my disposal for study. The material comprises thirteen species of Aphididæ, of which five are new to science, and about thirty species of other Rhynchota. The type specimens of the new forms described here are deposited in the Imperial Pusa Collection, Laboratory of the Imperial Entomologist, I.A.R.I., New Delhi.

I express my heartfelt thanks to Dr. H. S. Pruthi, the Imperial Entomologist and to Dr. Taskhir Ahmad, for giving me an opportunity of studying this interesting material and to the former for facilities for work, constant encouragement, guidance and criticism. My thanks are also due to my colleague, Mr. M. S. Mani, for going through the manuscript of this paper and making many useful suggestions.

APHIDIDÆ

Aphis laburni Kaltenbach

Kaltenbach, *Monogr. Pflanzenläuse*, p. 85 (1843).

I have before me, a large number of alate and apterous viviparous females and nymphs of this species collected from Paghman on 29.vi.39 and from Ghazni on 18.vii.39, infesting willow in both the localities.

This shiny black aphid is a cosmopolitan species, occurring mainly on leguminous crops.

*Buckton in Aitchinson, *Trans. Linn. Soc.*, **5**: 141-142, (1889).

†Kiritshenko, A. N., *Arb. Morph. Taxon. Ent.*, **5**: 1-8, (1937).

Anuraphis sp., prox. (?) *helichrysi* (Kalt.)

Alate viviparous female (Figs. 17-20).

Size and general colour.—Small in size, 1 to 1.3 mm. long. Head and antennæ almost concolorous, brownish-yellow. Eyes black. Flagellum of the sixth antennal segment a little lighter in colour than the rest of antenna. Mesothorax and metanotum dark brown, rest of thorax yellow. Coxa, trochanter, apical half of femur and apex of tibia brown; tarsus light brown, rest of leg, specially the tibia creamy-yellow. Stigma and veins dark yellow. Abdomen yellow. Cornicles, cauda and anal plate very light brown, almost concolorous with the abdomen. The margins of anal plate and cauda brown.

Head and appendages.—Width of head across eyes 0.3 mm. Antenna (Fig. 17) of six segments, 0.8 mm. in length. First antennal segment gibbous, almost as long as the second segment, relative proportions of the various segments 10 : 10 : 58 : 28 : 18 : 17+53. Secondary round sensoria restricted to the third antennal segment (Fig. 18), 12-14 in number, on one side, distributed over almost the whole length of the segment. Near the top of the fifth segment there is a large round primary sensorium; at the base of the flagellum of the sixth antennal segment there is a large sensorium together with a few small ones around it.

Thorax and appendages.—Forewings well developed, about 2 mm. long, venation normal. Rostrum about 0.4 mm. long, extending up to the middle of mesosternum. Hind tibia long and thin, 0.65 mm. in length. Hind metatarsus .02 mm. and the second tarsal joint 0.1 mm. in length.

Abdomen.—Spiracles round, prominent with dark brown areas at their bases. Cauda (Fig. 20) short and broad, more or less round, furnished with about half a dozen long hairs. Anal plate round (Fig. 20), furnished with numerous long hairs. Cornicles (Fig. 19) short, thick, cylindrical, expanded basally, a prominent flange at the apex; 0.07-0.08 mm. long, almost equal to the fifth antennal segment.

It is possible that this aphid is only one of the numerous varieties of *A. helichrysi* (Kalt.),* so far known from different parts of the palæarctic region.

This insect was doing very serious damage to peach, almond and Iris lily at Kabul and at Istalif near Kabul. The leaves were curled and very much distorted.

Hyalopterus arundiniformis, sp. nov.

Alate viviparous female (Figs. 1—6).

*Kaltenbach, *Monogr. Pflanzenlaüse*, p. 102 (1843) (*Aphis*).

Size and general colour.—Elongate-oval. Length of body from vertex to the tip of anal plate 1.54 to 1.7 mm. Head brownish, eyes red. Rostrum yellow, tip black. Antennæ light yellow, apices of segments dusky, particularly of the fifth and sixth. Pronotum light brown, thoracic lobes and sternum dark brown; pleuræ and wing insertions yellow; wings hyaline; stigma and veins grey. Legs yellow, apices of tibiæ and tarsi light grey. Abdomen yellow, cauda and cornicles essentially concolorous with the abdomen; anal plate darker and with long hairs. Two longitudinal rows of small dark brown spots often present on the dorsum of the abdomen. Prothorax and abdominal segments with a pair of pale blunt tubercles on their lateral sides.

Head and appendages.—Width of head (Fig. 1) across eyes 0.35 to 0.39 mm. Antenna (Fig. 2) 1.15 to 1.4 mm. long, of six segments with relative proportions of 3 : 3 : 15 : 11 : 9 : 4+15. Secondary sensoria typically limited to the third antennal segment (Fig. 3), on one side almost in a row, occasionally in a spiral, numbering 9-16. Rarely there are 1-4 secondary sensoria on the fourth antennal segment of one or both antennæ. Primary sensoria present on the fifth and sixth segments, the one on the sixth surrounded by a group of small sensoria on its one side. Rostrum pale, short and thick, reaching nearly to second pair of coxæ; and 0.33 mm. long.

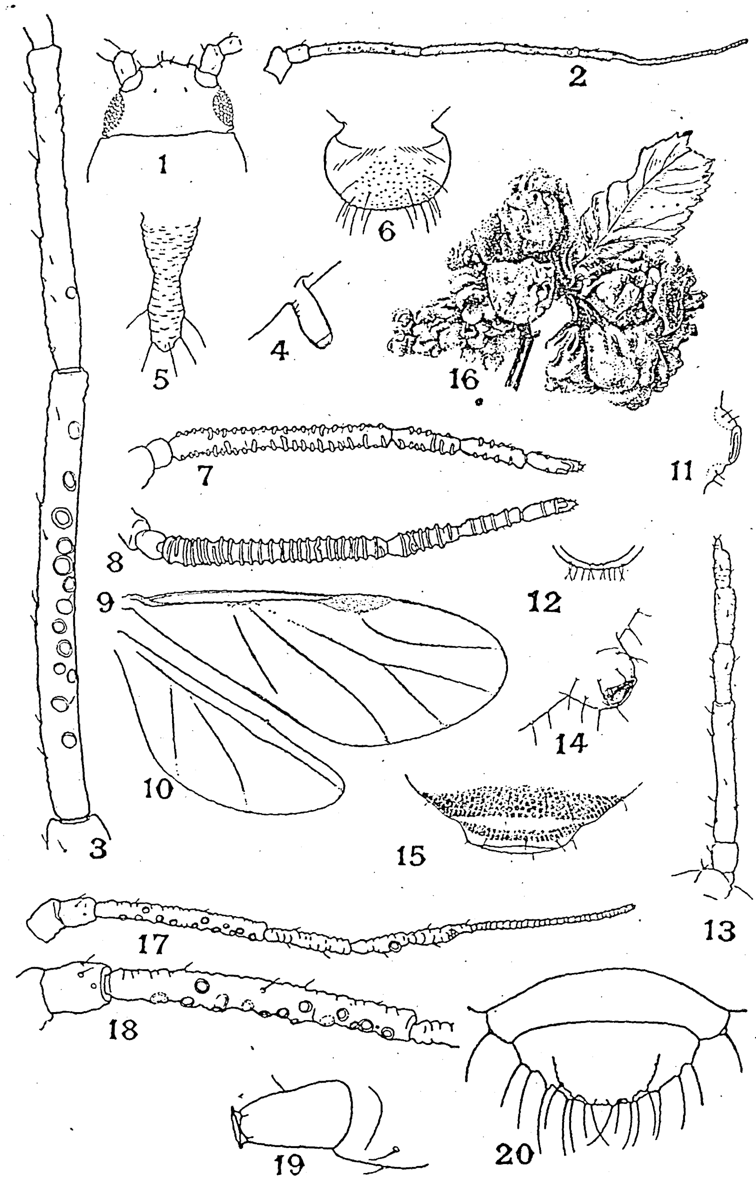
Thorax and appendages.—Forewings 2.2 to 2.64 mm. long. Median vein twice-branched, cubital and anal veins present. Tarsi normal, hind metatarsus 0.033 mm. and the second tarsal segment 0.11 mm. long.

Abdomen.—Width of abdomen 0.594 to 0.814 mm. Cornicles (Fig. 4) very small, faintly imbricated near the base, 0.066 to 0.088 mm. long, slightly more than twice their own width, constricted near the middle and somewhat swollen beyond. Cauda (Fig. 5) long, constricted in the middle, 0.154 to 0.198 mm. long, typically longer than and occasionally equal to but never less than twice the length of the cornicles. Two pairs of lateral and one single median dorso-apical hairs present on the cauda. Anal plate (Fig. 6) furnished with a large number of hairs.

Apterous viviparous female.

Size and general colour.—Elongate-oval, 1.9 to 2.2 mm. long. General colour pale yellow, head slightly darker. Eyes dark red. First and second antennal segments concolorous with the head, third and fourth pale hyaline, apices of fifth and sixth segments grey. Apices of femora, tibiæ and the entire tarsi grey. Cauda somewhat dusky in the apical half; rest of the cauda and cornicles pale yellow.

Head and appendages.—Width of head across eyes 0.396 to 0.44 mm. Antenna 1.3 to 1.5 mm. long, of six segments with relative proportions of



Figs. 1-6. *Hyalopterus arundiniformis*, sp. nov. (Alate viviparous female).
1. head × 95 ; **2.** antenna × 95 ; **3.** third and fourth antennal segments × 380 ; **4.** cornicle × 185 ; **5.** cauda × 185 ; **6.** anal plate × 185.

Figs. 7—12. *Eriosoma taskhiri*, sp. nov. (Alate viviparous female).
7. antenna × 140, ventral view ; **8.** antenna × 140, dorsal view ; **9.** forewing × 42 ; **10.** hind wing × 42 **11.** corincle × 360 ; **12.** cauda and anal plate × 140

Figs. 13-16. *Eriosoma taskhiri* sp. nov. (Apterous viviparous female).
13. antenna × 120 **14.** cornicle × 240 ; **15.** hind end of the abdomen showing polygonal cells × 115 ; **16.** gall on poplar × $1\frac{1}{2}$

Figs. 17-20. *Anuraphis* sp. prox. (?) *helichrysi* Kalt. (alate viviparous female).
17. antenna × 198 ; **18.** second and third antennal segments × 350 **19.** cornicle × 350; **20.** hind end of the abdomen showing cauda and anal plate × 350.

8 : 7 : 32 : 22 : 20 : 9+32. Rostrum short and thick reaching nearly to second pair of coxæ, 0.33 mm. in length.

Thorax and appendages.—Prothorax with a pair of small lateral tubercles. Tarsi normal; hind metatarsus 0.044 mm. and the second segment 0.11 mm. in length.

Abdomen.—Each abdominal segment has a pair of small lateral tubercles, one on each side. Cornicles very small, very faintly imbricated, 0.088 to 0.11 mm. long, longer than twice the width of each cornicle, constricted near base, somewhat swollen in the middle, mouth not flaring. Cauda long, constricted in the middle, sometimes without a constriction, 0.22 to 0.242 mm. long, longer than twice the length of cornicles. Two pairs of lateral and a single median dorso-apical hairs present on the cauda.

Holotype.—Alate viviparous female collected on apricot at Kabul on 28-vi-39, mounted on slide (I.P.C. No. R/8028). Apterous viviparous female collected along with the alate form. On slide (I.P.C. No. R/8029).

Paratypes.—Alate and apterous viviparous females on slides (I.P.C. No. R/8030-8038).

The Imperial Pusa Collection also contains a number of specimens of this species, on slides and preserved in alcohol, collected by Ahmad on peach and apricot at Kabul on 28.vi.39 and 28.vii.39 and on bamboo on 30.vi.39.

Systematic position.—This species is closely related to *Hyalopterus arundinis* (Fabr.),* from which it differs in not having ensiform cauda and in the shorter cornicles, which are never longer than half the length of cauda. Typically there are no secondary sensoria on the fourth antennal segment. There are fewer sensoria on the third and none on the fifth antennal segment.

This species appears to be very common in Afghanistan and had been found doing severe damage to peach, plum, apricot and bamboo, especially in the garden of the British Legation at Kabul. The leaves of the infested trees get twisted and curled, thus adversely affecting the growth of the trees. A closely related species, *H. arundinis* (Fabr.),* is very harmful to peach, plum, etc., in other parts of the world, including Baluchistan and the N. W. F. Province in India.

Macrosiphum rosæ (Linn.)

Linnaeus, *Syst. Nat.*, **2** : 734 (1735) (*Aphis*).

There are a large number of alate and apterous viviparous females and nymphs in the collection before me, taken on rose at Kabul on 28.vii.39.

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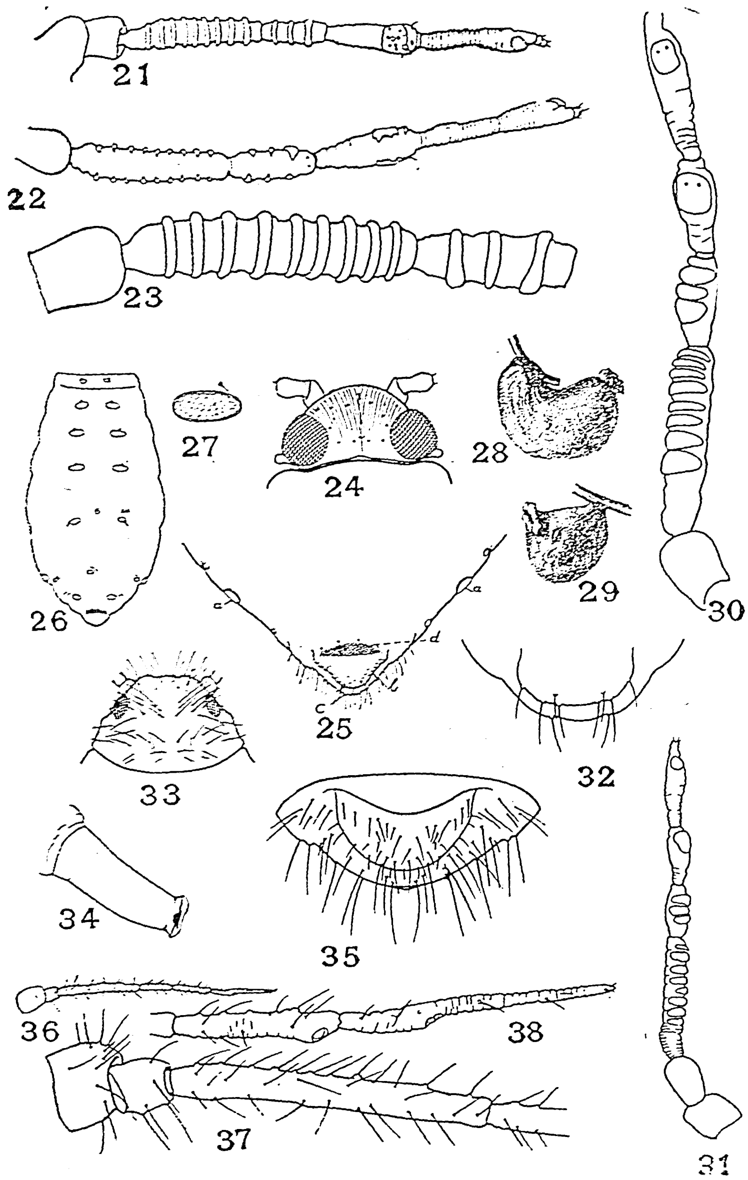
* Fabricius, *Ent. Syst.*, **4** : 212-213 (1794) (*Aphis*).



Figs. 21-29. *Pemphigus paghmanensis*, sp. nov. (Alate viviparous female).

21. Antenna × 150, dorsal view ; 22. antenna × 150, ventral view ; 23. second, third and fourth antennal segments × 377 ; 24. head × 93 ; 25. hind end of abdomen × 153 showing, (a) cornicles (b) cauda, (c) anal plate, (d) wax-pore plate ; 26. metanotum and abdomen showing the arrangement of wax-pore plates × 45 ; 27. a wax-pore plate × 240 ; 28. and 29. galls on poplar twigs × 1½

Figs 30-32. *Pemphigus spirothecœfacies* sp. nov. (Alate viviparous female).

30. antenna × 300 ; 31. antenna × 176 ; 32. cauda and anal plate × 255.

Figs 33-38. *Ptrerocomma* sp. prox. *populea* (Kalt.) (Apterous viviparous female).

33. head × 53 ; 34. cornicle × 190 ; 35. cauda and anal plate × 190 ; 36. antenna × 53 ; 37. first, second and third antennal segments × 190 ; 38. fifth and sixth antennal segments × 190.

This species is so far known from Egypt, Java, Japan, Argentina, Brazil and U. S. A. An allied species, *M. rosæiformis* Das, occurs on rose in India.

Macrosiphum pisi (Kaltenbach)

Kaltenbach, *Monogr. Pflanzenläuse*, p. 23 (1843) (*Aphis*).

I have specimens of this large-sized aphid, taken on berseem at Kabul on 30.vi.39 and on bean at Bamian on 5.vii.39.

It is widely distributed in Europe, America, Africa, India and Japan; sometimes it does considerable damage to pea and bean in these countries.

Chromaphis juglandicola (Kaltenbach)

Kaltenbach, *Monogr. Pflanzenläuse*, p. 151 (1843) (*Aphis*).

There are a large number of specimens in the collection before me. This species was fairly abundant on walnut at Kabul on 24.vi.39 but no appreciable damage had been done to the leaves.

It is a serious pest of walnut in Europe and America, especially in California.

Callipterus juglandis (Frisch)

Frisch, *Insecta*, **11**, (12) : 10 (1750) (*Aphis*).

There are only a few alate viviparous females, taken breeding on walnut at Paghman on 26.vi 39, in the collection before me.

In England this species occurs in large numbers on the upper surface of walnut leaves. It is also found in Switzerland.

Chaitophorus pseudotremulæ, sp. nov.

Alate viviparous female (Figs. 39—42).

Size and general colour.—Specimens preserved in spirit brownish-yellow. The entire body including legs and antennæ covered over with long hairs. Hairs of various shapes, some thick and bifurcated, specially on the head; others thin and long. Eyes red. Rostrum brown. Head, first and second antennal segments, apices of fourth, fifth and sixth antennal segments; pronotal collar; broad median bars on the dorsum of the abdominal segments; a spot on the lateral sides of each of the anterior five abdominal segments, a large spot at the base of each of the cornicles, a large number of small spots on the abdomen above and beneath; genital plate; bases of tibiæ and tarsi, coxæ, trochanters and femora of the first two pairs of legs dark brown. Meso- and metathorax and hind legs, except apical two-thirds of tibiæ, very dark brown or almost black. Cauda and anal plate yellow, occasionally light brown, cornicles dark brown.

Head and appendages.—Width of head (Fig. 39) across eyes 0.442 mm. Antenna (Fig. 39) 1.45 mm. long, of six segments with relative proportions of 19 : 17 : 110 : 52 : 51 : 29+52, first segment broader than the second. Base of the sixth antennal segment always more than half the length of flagellum. 16-20 round, scattered sensoria on one side of the third (Fig. 40) and 0-2 on the fourth antennal segment. Usual primary sensoria on the fifth and sixth antennal segments. A long spine at the apex of the flagellum. Rostrum 0.704 mm. in length extending up to the middle coxæ, rarely passing beyond them.

Thorax and abdomen.—Wings and tarsi normal. Cornicles (Fig. 41) short, truncate, more or less broad basally, apices reticulate, 0.132 mm. long. Cauda (Fig. 42) distinctly knobed, 0.094 mm. in length, with 6-8 long curved hairs on the knob. Knob projects beyond the abdomen. Anal plate (Fig. 42) round, furnished with numerous hairs.

Apterous viviparous female (Fig. 43).

Oval or elongate oval, 1.8 mm. long. Body (Fig. 43) dark brown to black, furnished with long hairs which are generally bifurcate at the top. Eyes red. Antennæ of six segments, very dark brown, except third and fourth segments, which are lighter in colour. The relative proportions of the antennal segments 4 : 3 : 20 : 10 : 9 : 5+10. The first segment is broader and more gibbous than the second. Rostrum long, 0.65 mm., passes the posterior pair of coxæ reaching the anterior margin of the second abdominal segment. Coxa, trochanter, femur, and base of tibia dark brown to almost black. Tarsi normal. Hairs on antennæ and legs short and simple. Anal plate round, light brown with long hairs. Cauda knobed, pale yellow, with four long and two short hairs on the knob; cornicles short, truncate, dark brown, with reticulations at the apices, slightly longer than cauda.

Holotype.—One alate viviparous female taken on poplar at Kabul on 25.vi.39, mounted on slide (I. P. C. No. R/8039). Apterous viviparous female collected along with the alate form is also on the same slide.

Paratypes.—In the collection there are a large number of alate and apterous viviparous females on slides (I. P. C. No. R/8040-8045).

Systematic position.—This species comes very close to *Chaitophorus tremulæ* Koch,* from which it differs in the colour of cauda, which is yellow or yellowish-green but not black; different shape of the cauda, specially the knob; the proportion of base and flagellum of the sixth antennal segment which is 1 : 2 and not 1 : 3 as in *tremulæ* Koch.

This species was fairly common on poplar at Kabul on 25.vi.39, but there was no curling of the leaves.

**Die Pflanzenläuse*, pp. 8 and 12 (1854).

Pterocomma sp., prox. *populeum* (Kaltenbach)

Apterous viviparous female (Figs. 33-38).

The whole insect hairy, somewhat oval in shape 2.7-3.0 mm. long. General colour of specimens preserved in spirit dark brownish-yellow. First antennal segment, apices of the second and fifth, apex and base of the sixth segment (Fig. 38) dark brown; rest of the antenna dark dirty-yellow, 1.2-1.34 mm. in length (Figs. 36-38). The proportions of the antennal segments are 4 : 3 : 20 : 8 : 9 : 5+9. Eyes red. Base and tip of rostrum dark brown, rest lighter in colour; 0.9 to 1.0 mm. in length extending up to the third abdominal segment. (In nymphs rostrum extends to the middle of mesosternum). Coxa, apex of femur and entire tarsus dark brown; rest of the leg lighter in colour. Hind tibia 1.2 mm. in length, hind metatarsus 0.04 mm. and second joint of the hind tarsus 0.13 mm. long. Prothorax with a prominent tubercle on each lateral side. Abdomen dark yellow; dark brown spots on the lateral sides of the abdomenal segments, each spot with a central tubercle. There are small transverse black spots dorso-laterally one on each of the body segments, forming two longitudinal rows from the head to the cauda and passing between the eyes and cornicles. Cauda (Fig. 35) short, semilunar to broadly angular in shape; anal plate (Fig. 35) round; both concolorous with the body and furnished with thin long hairs. Cornicles (Fig. 34) yellow, almost cylindrical, in some broader at the base; apex dark brown, 0.17-0.2 mm. long. Two dark longitudinal bands on each side of the central, broad yellow area on the ventrum of the abdomen converging towards the posterior end.

Notes.—This species is very close to *Pterocomma populeum* (Kalt.).* The apterous viviparous females were found breeding in large numbers on poplar stem at Paghman on 29.vii.39.

Pterochlorus saligna (Gmelin)

Gmelin, *Syst. Nat.*, **62** : 2209 (1788) (*Aphis*).

The material of this large black aphid before me was collected from willow stems at Paghman on 29.vii.39.

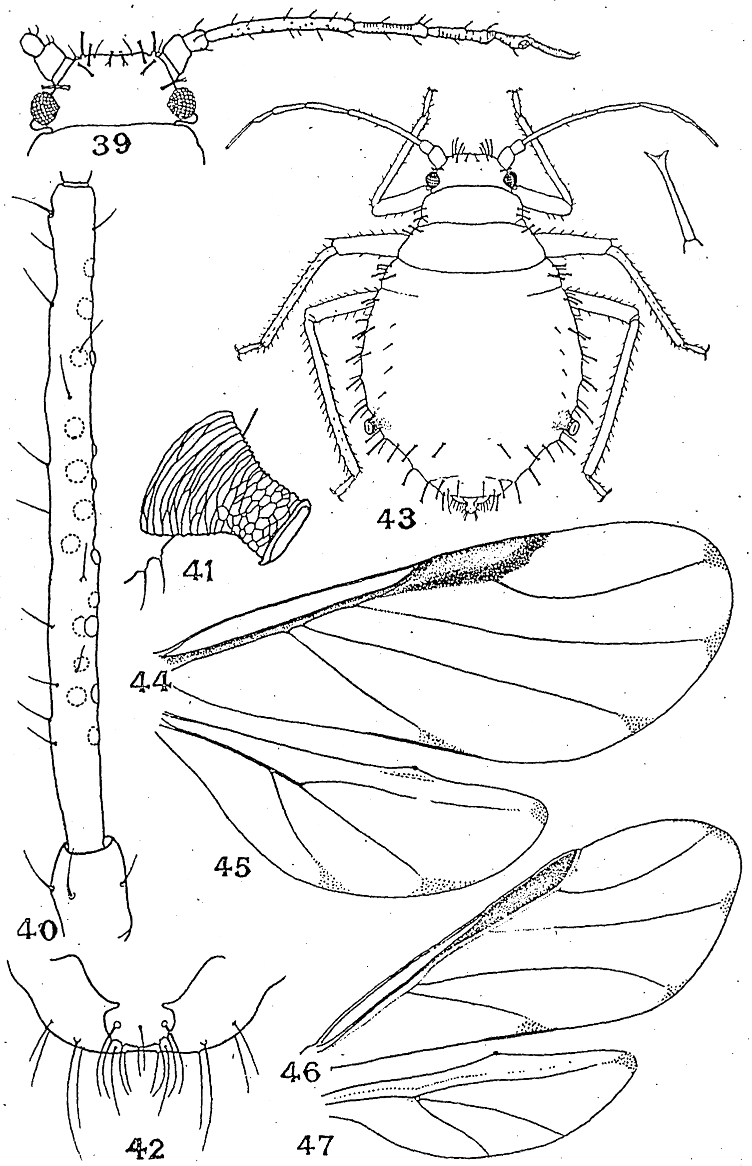
This species is widely distributed and is recorded from Europe, Egypt, India, Japan, China, Mexico and U. S. A. In England it does considerable damage to willow and osier and sometimes to poplar also.

Pemphigus paghmanensis, sp. nov.

Alate viviparous female (Fundatrigenia) (Figs. 21—29, 44—45).

Size and general colour.—Length of body from vertex to anal plate

*Kaltenbach, *Monogr. Pflanzenläuse*, p. 116 (1843) (*Aphis*).



Figs. 39-42, *Chaitophorus pseudotremulæ*, sp. nov. (Alate viviparous female).

39. head and antenna × 95 ; **40.** third antennal segment × 95 ; **41.** cornicle × 396 ; **42.** cauda and anal plate × 396.

Fig. 43. *C. pseudotremulea*, sp. nov. (Apterous viviparous female).

43. female highly enlarged.

Figs. 44-45. *Pemphigus paghmanensis*, sp. nov.

44. forewing × 50 ; **45.** hind wing × 50.

Figs. 46-47. *Pemphigus spirothecæfacies*, sp. nov.

46. forewing × 48 **47.** hind wing × 48.

2.43 mm. Specimens preserved in spirit brownish-yellow. Antennæ, head, thoracic lobes, mesopleuræ, meso- and meta-sterna, scutellum, anterior margin of pronotum and legs dark brown. Eyes, costa, stigma, pro- and metanota, rest of the meso- and meta-thorax, base and tip of rostrum, genital plate and posterior margin of cauda light brown. Antennal sockets, basal areas of antennal segments, middle portion of rostrum, prothorax excluding pronotum, acetabulæ of the coxæ, the basal areas of the joints of the legs and the entire abdomen brownish-yellow or greyish-yellow.

Head and appendages.—Width of head (Fig. 24) across eyes 0.45 mm. Antenna (Figs. 21-22) 0.71-0.79 mm. long, of six segments with relative proportions of 6 : 6 : 20 : 10 : 14 : 16+3. The second antennal segment is sometimes longer than the first but is always slender. Secondary annular sensoria typically limited to the third and fourth antennal segments (Fig. 23), encircling about two-thirds of the circumference of the segment, numbering 7-11 on the third and 2-4 on the fourth. Occasionally there is one secondary annular sensorium on the fifth antennal segment. Near the apex of the fifth antennal segment encircling about three-fourths of its circumference there is a large primary sensorium having a number of minute chitinous island-like areas and a few spines. The length of the fifth antennal segment below the primary sensorium always longer than the length of the sensorium plus the length of the segment above it. There is a fairly big sensorium at the base of the flagellum of the sixth antennal segment. The basal portion of the sixth segment partially imbricated. Rostrum passes the anterior pair of coxæ but does not reach the second pair and is 0.44 mm. in length.

Thorax and appendages.—Tarsi normal. Metatarsus 0.031 mm. and the second segment of the hind tarsus 0.175 mm. long. Metanotum (Fig 26) with a pair of small wax-pore plates. Veins ending a considerable distance before margin of wings (Fig. 44). Cubitus of the hind wing (Fig. 45) arises much ahead of the median.

Abdomen.—(Fig. 26) A pair of oval, transversely elongated wax-pore plates (Fig. 27) on each of the first, second and third abdominal segment; two small and two large ones on the fourth; three small ones on the sixth, two near the cornicles and one in the middle; two medium-sized on the seventh and a large transversely elongated (Fig. 25, d) occasionally curved on the last abdominal segment, just in front of the cauda, present on the dorsal side. Each wax-plate with a single hair in front of the anterior margin except the last one, which has four hairs. Cornicles (Fig. 25, a) present as mere pores. Cauda (Fig. 25, b) and anal plate (Fig. 25, c) round.

Holotype.—An alate viviparous female collected from galls on poplar at Kabul on 24.vi.39, on slide (I. P. C. No. R/8046).

Paratypes.—Several alate viviparous females on slides and preserved in alcohol (I. P. C. No. R/8047-8051).

This aphid produces galls (Fig. 28-29) on poplar which are subglobose or pear-shaped and a little recurved in shape, measuring about 12 to 25 mm. in length and 10-20 mm. in breadth. They are formed in the axils of leaves. At the posterior end of the gall there is an elongate-oval opening through which the aphids can come about. Numerous galls on poplar in a nursery at Kabul were found by Ahmad on 24.vi.39.

Systematic position.—This species is closely allied to *Pemphigus lichtensteini* Tullgren,* which produces similar galls on poplar in Italy. It differs from *P. lichtensteini* in the following characters :—

(1) Median and cubitus of hind wings do not arise from almost the same place. The cubitus arises far ahead of the median unlike in *lichtensteini*.

(2) The primary sensorium on the fifth antennal segment is very large; its length is always much more than half the length of the part of fifth antennal segment below this sensorium. The heavily chitinised island-like areas in this sensorium are more numerous than those in the case of *lichtensteini*.

Pemphigus spirothecæfacies, sp. nov.

Alate viviparous female (Fundatrigenia) (Figs. 30-32 and 46-47).

Size and general colour.—Small in size 1.4 to 1.6 mm. long. Colour of specimens, preserved in alcohol, yellow. Head and thorax very dark brown to almost black. Eyes black. Antennal segments almost uniformly brown. Legs brown. Abdomen yellow. Cauda and anal plate concolorous with the abdomen.

Head and appendages.—Width of head across eyes 0.32 mm. Antenna (Figs. 30-31) always six-segmented, short, 0.54 mm. in length. The proportions of the various antennal segments are 10 : 14 : 38 : 17 : 18 : 22+5. Fourth and fifth antennal segments are some times equal. 7-8 broadly annular secondary sensoria on the third antennal segment, 2-3 on the fourth antennal segment, rarely 0-1 on the fifth segment, encircling a little more than half the circumference of the various segments. One large round primary sensorium at the top of the fifth and another at the base of the flagellum of the sixth antennal segment. Flagellum short, furnished with a few short thick spines at the apex. Rostrum short about 0.5 mm. in length, reaching up to the middle of the meso-sternum.

Thorax and appendages.—Forewings (Fig. 46) 2.5 mm. in length. Median once-branched, poorly developed in the anterior one-fourth length. Hind wings (Fig. 47) with both median and cubitus arising from almost the same place. Legs normal. Hind tibia about 1 mm. long, hind meta-

* Tullgren, *Arkiv. Zool.*, 5 (14) : 148 (1909).

tarsus 0.03 mm. and second tarsal joint 0.15 mm.

Abdomen.—Cauda and anal plate round (Fig. 32), furnished with a few long hairs. Wax-pore plates poorly developed, 2-4 only discernible, with some difficulty on the anterior half of the abdomen. Cornicles apparently wanting.

Holotype.—An alate viviparous female collected from galls on poplar at Amar-Khail near Kabul on 18.vii.39, on a slide (I.P.C. No. R/8052).

Paratypes.—Large number of alate viviparous females on slides and preserved in alcohol (I. P. C. No. R/8053-8059).

Systematic position.—This species comes very close to sexupara of *Pemphigus spirothecæ* Passerini.* The number of secondary sensoria on the third and fourth antennal segments and the general appearance are almost the same in both cases. Cornicles are absent in both. But these specimens are fundatrigenia, which differ from fundatrigenia of *spirothecæ* in the following characters :—

1. All the females have six-segmented antenæ unlike *spirothecæ*, which sometimes have only five segments.

2. The proportions of the antennal segments and the lengths of the antennæ are quite different.

3. Wax-pore plates are very poorly developed in this species.

Eriosoma taskhiri, sp. nov.

Alate viviparous female.

Size and general colour.—Length 2 to 2.2 mm. Colour dirty brownish-yellow in specimens preserved in spirit. Head, thoracic lobes, mesonotum, mesopleuræ, mesosternum and scutellum very dark brown to almost black. Face, antennæ, eyes, legs, base and tip of rostrum, genital plate and posterior margin of cauda light brown. Antennal sockets, basal areas of the antennal segments middle portion of the rostrum, prothorax, acetabulæ, basal areas of the leg joints and the entire abdomen brownish-yellow or greyish-yellow. Wing insertions, costa and stigma dark dirty yellow. Legs brownish-yellow.

Head and appendages.—Antenna (Figs. 7 and 8) 0.78 to 0.9 mm. long, six-jointed. The lengths of the antennal segments vary in different individuals, average proportional lengths of the various segments 12 : 12 : 98 : 30 : 28 : 13+7. Secondary sensoria annular, incompletely encircling the segments ; typically present on the third to sixth antennal segments, numbering 22-30 on the third, 5-9 on the fourth, 5-8 on the fifth and 1-2 on the sixth. Primary sensorium is absent from the fifth but present on

*Passerini, *Gli Afidi*, p. 39 (1860).

the sixth segment ; branched and furnished with short spines on its circumference. Flagellum of the sixth antennal segment short and thick, about half the length of the base, furnished with 3-5 short spines. Rostrum reaches the anterior margin of the second pair of coxæ, about 0.58 mm. in length.

Thorax and abdomen.—Forewings (Fig. 9) with median once branched, near middle and is nearly obsolete near base. In the hind wings (Fig. 10) both median and cubitus present. Hind metatarsus is 0.02 mm. and the second tarsal joint 0.15 mm. in length. Length of the hind tibia is 0.8 mm. and that of the forewings 2.8 mm.

Cauda and anal plate round (Fig. 12). Anal plate furnished with long hairs. Two large hairs on the apex of cauda. Cornicles (Fig. 11) short, situated on broad hairy cones.

Apterous viviparous female.

Length of body from vertex to anal plate 2.0-2.2 mm. Width of head across eyes 0.46 mm. General colour light brownish-yellow in specimens preserved in spirit. First to fourth antennal segments light yellow. Fifth and sixth antennal segments and legs darker in colour than the rest of body. Compound eyes very poorly developed. Antenna (Fig. 13) 0.7-0.8 mm. long, of six segments with relative proportions of 9 : 9 : 41 : 17 : 16 : 10+3, fourth and fifth segments sometimes equal in length. Flagellum short and blunt. Rostrum 0.73 mm. long, extending a little beyond the second pair of coxæ. Hind metatarsus 0.02 mm. and the second tarsal segment 0.12 mm. long. Hind tibia 0.63 mm. in length. Body probably covered over with wax in nature. Most of the dorsal surface of the head, thorax and abdomen furnished with polygonal cells (Fig. 15), particularly prominent over the sixth to eighth abdominal segments. Cauda and anal plate round. Cornicles (Fig. 14) short, slightly truncate, situated on broad cones furnished with hairs ; a few hairs present on the cornicles as well.

Holotype.—An alate viviparous female collected from galls on poplar at Kabul on 26.vi.39, on a slide (I.P.C. No. R/8060). An apterous viviparous female collected along with the alate form is also on a slide (I. P. C. No. R/8061).

Paratypes.—Several alate and apterous viviparous females on slides (I. P. C. No. R/8062-8066).

Notes.—This aphid produces spongy irregular galls on the terminal twigs of poplar (Fig. 16). The galls are of different sizes, varying from 15-35 mm. in length and breadth. At some places these galls are grouped together to resemble a big spongy mass. These galls are almost similar to those of *Mordwilkoja vagabunda* (Walsh)* in Illinois (U.S.A.).

* Walsh, *Proc. ent. Soc. Philadelphia*, **1** : 306 (1862) (*Byrsocrypta*).

PENTATOMIDÆ

Dalpada sp.

Amyot et Audinet-Servillé, *Hist. Nat. Ins. Hempt.*, Paris, p. 105 (1843).

There is only a single male specimen taken on bean at Chardeh on 4.vii.39. The fourth and fifth antennal segments and legs are broken. The specimen is ochraceous-brown, coarsely punctate, lateral sides of the abdomen beneath a little more finely punctured, connexivum above and below with black spots. First antennal segment concolorous with the body, the second and third segments black.

Eusarcocoris inconspicuus (Herr.-Schäff.)

Herrich-schäffer, *Wanz. Ins.*, **7** : 93 (1844) (*Pentatoma*).

The single male specimen was collected at light from Kunduz on 8.vii.39.

This species is previously known from the Palæarctic, Aethiopian and Oriental regions.

Brachynema cincta (Fabr.)

Fabricius, *Syst. Ent.*, p. 712 (1775) (*Cimex*).

I have before me a male specimen collected at light from Haibak on 5.vii.39 and a female on apricot at Kandahar (3425 ft.) on 24.vii.39.

This species is previously recorded from Europe and Algeria.

Rhaphigaster nebulosa (Poda)

Poda, *Ins. Mus. Gr.*, p. 56 (1761) (*Cimex*).

The material before me comprises four nymphs and four females collected on apricot at Kandahar (3425 ft.) on 24.vii.39.

Eurydema festivum var. **chloroticum** Horvath*

Horvath, *Rev. Ent.*, **10** : 78 (1891).

There are two males collected on carrot from Doaba on 14.vii.39.

Eurydema festivum var. **pictum** (Herr.-Schäff.)

Herrich-Schäffer, *Panz. Faun. Germ.*, p. 116 (1834) (*Pentatoma*).

There is a male and a female specimen collected from Doaba on 14.vii.39 along with *E. festivum chloroticum.*

Eurydema festivum, var. **decoratum** (Herr.-Schäff.)

Herrich-Schäffer, *Panz. Faun. Germ.*, p. 116 (1834) (*Pentatoma*).

**Eurydema festivum* var. *chloroticum* is common in India and the Philippines, where it attacks cruciferous crops among others.—M. S. Mani.

In the collection there is a male and a female taken on carrot from Doaba on 14.vii.39 along with the above two varieties and one female from Kandahar taken on apricot on 22.vii.39.

These varieties of *E. festivum* are widely distributed and the previous records are from Europe, North Africa, Canary Isles, Syria, Turkestan, Kashmir and China.

Carpocoris fuscispinus Boh.

Bohmann, *Svensk. Vet.-Akad. Hand.*, p. 241 (1849).

In the material before me there is a male and a female collected on carrot from Doaba on 14.vii.39. The female is darker in colour than the male. The clavus and corium in male are pale ochraceous, whereas in the female they are dirty purple.

This species occurs throughout the Palæarctic region descending down to the north coast of Africa.*

TINGIDIDÆ

Stephanitis pyri (Fabr.)

Fabricius, *Syst. Rhynch.*, p. 126 (1803) (*Tingis*).

There are about two dozen specimens collected on apple at Kandahar (3425 ft.) on 23.vii.39. The nymphs and adults of this lace-bug were fairly common on apple leaves at the time of the visit of the Delegation.

It has been previously recorded from Syria and Europe.†

Monostira unicostata Muls. & Ray

Mulsant et Ray, *Ann. Soc. Linn. Lyon*, p. 134 (1852).

The material before me consists of a large number of male and female specimens collected on willow and poplar at Kandahar (3425 ft.) on 27.vii.39. At the time of the Delegation's visit the bugs were breeding extensively on the leaves thus causing a rather very serious damage to these trees.

This species is widely distributed and is previously recorded from Europe, Algeria and America.

REDUVIIDÆ

Pasira perpusilla (Walk.)

Walker, *Cat. Het.*, **7** : 196 (1873) (*Reduvius*).

There is a single male specimen of the species collected at light from

* Sacharov reported this species as an important pest of flax on Russia-Afghanistan border-area in 1914.—M. S. Mani.

† Also from Mesopotamia, Japan and South-east Asiatic Russia.—M. S. Mani.

Kandahar (3425 ft.) on 25.vii.39.

Basal areas of clavus and corium in this specimen are reddish-luteous and not luteous as is generally the case in this species.

It has been previously recorded from North Bengal and Burma.

Ectomocoris sp.

Mayr, *Verh. zool.-bot. Ges. Wien*, **15** : 438 (1865).

The single male specimen before me was collected at light from Kandahar (3425 ft.) on 25.vii.39. It is piceous-black. Second, third and fourth antennal segments, apex of rostrum, apices of tibia, ventral tibial groove and tarsi piceous-brown; a sub-basal, a transverse discal and an apical spot on hemelytra pale luteous.

Ectomocoris sp., prox. *ochroptera* Stål

The single male specimen collected at light at Kandahar on 21.vii.39 comes very near *E. ochroptera* Stål* but differs in the following characters:

Antennæ, rostrum, legs, clavus, corium, basal third and apex of membrane, lateral margins of abdomen luteotestaceous; inner margin of clavus, a transverse fascia on corium, coxæ and the rest of the body black.

Pirates mundulus Stål

Stal, *En. Hemipt.*, **4** : 58 (1874).

There is a male and a female specimen collected at light at Kunduz (1100 ft.) on 8.vii.39.

This species has been previously recorded from India (Tranquebar, Dacca, Saran and Borghat) and Ceylon.

Sirthenia flavipes (Stål)

Stal, *Ofv. Svenska Vet.-Akad. Forh.*, p. 187 (1855) (*Rasahus*).

There is one female specimen collected at light from Kandahar on 25.vii.39. The whole of the basal half of corium is luteous in this specimen. When the elytra are closed this luteous area forms a horse-shoe shaped band.

This species is known to occur in India, Ceylon, Java, Borneo, Philippines, Japan and Formosa.

Oncocephalus klugi Dist.

Distant, *Faun. Brit. India*, Rhynchota, **2** : 230 (1904).

* Stal, *Ofv. Svenska. Vet.-Akad. Forh.*, p. 256 (1866).

There is only one female specimen of this species collected at light from Kunduz (1100) on 8.vii.39. This species has been previously recorded from India and Burma.

Nabis indicus (Stål)

Stal, *En. Hemipt.*, **3** : 114 (1873) (*Aspilaspis*).

In the collection there is only a female specimen taken on cotton at Kunduz on 8.vii.39. It is previously known from North India.

CAPSIDÆ

Adelphocoris lineolatus (Goeze)

Goeze, *Ent. Beitr.*, **2** : 267 (1778) (*Cimex*).

In the material before me there is a male and a female from Mazari-Sharif (1237 ft.) on 10.vii.39 and two females from Kunduz on 8.vii.39 collected at light at both the places.

This is a palæarctic species and has been previously recorded from Breton Island and Nova Scotia on *Chenopodium* spp.*

Trigonotylus ruficornis (Geoffr.)

Geoffry, *Fourc. Ent. Par.*, p. 209 (1758) (*Cimex*).

There are three females collected on rice at Ammal-i-Khail, Ghazni (7280 ft.) on 18.vii.39 and a male one on cotton at Kunduz on 9.vii.39. The bugs were fairly common on rice.

This is a widely distributed species and has been previously recorded from Europe, Eastern North America, Quebec, New-England, Kansas and Colorado.

Lygus pratensis (Linn.)

Linnaeus, *Syst. Nat.*, (ed. 10) **2** : 448 (1758) (*Cimex*).

The collection contains material from the following localities :—

(*a*) Three males and two females from Bamian (9000 ft.) feeding on berseem, 4.vii.39 ; (*b*) One female on cotton from Kabul, 26.vi.39 ; (*c*) One female on maize from Haibak, 5.vii.39 ; (*d*) One female at light and two on cotton from Kunduz, 9.vii.39.

It was not found in appreciable numbers on any of the above crops in July 1939 in Afghanistan. This Capsid bug, known as the 'tarnished plant bug,' is a serious pest of various crops, specially pear and apple in America. Its distribution ranges all over Europe, Canada, U. S. A., and Mexico.

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* It occurs in Kashmir also, and in the south-east Asiatic Russia, where it is an important pest of lucerne, sugarbeet and cotton.—M. S. Mani.

ANTHOCORIDÆ

Anthocoris sp.

Fallen, *Hem. Seuc.*, p. 65 (1826-29).

There are a dozen specimens of a species of this genus in the material from Kabul taken on 28.vii.39. The nymphs and adults of this Anthocorid were fairly common and were feeding on the immature stages of *Bemisia* sp. infesting rose leaves.

SPECIES INCERTIS SEDIS

One Anthocorid adult from Ammal-i-Khail on rice collected on 18. vii.39.

CICADIDÆ

Psalmocharia rugipennis (Walk.)

Walker, *Ins. Saund. Homopt.*, p. 17 (1858) (*Cicada*).

There is one female specimen collected on *Artemisia* bush at Qalat-i-Ghilzai (5543 ft.) on 21.vii.39.

This species is already known from Quetta in India.

Paharia sp.

Distant, *Ann. Mag. Nat. Hist.*, (7) **16** : 25 (1905).

In the collection there are two males, one from Dakoo near Kābul, sitting on mulberry on 26.vi.39 and another from Chardeh on willow tree on 4.vii.39.

Dr. Ahmad in his diary writes :

" At both these places there were numerous cast skins sticking to the trunks of trees, on grass and even on the ground. Some adults were heard making the usual noise but when approached they flew away. The two adults captured were in the act of moulting. Numerous holes were found in the soil about one-fourth of an inch in diameter. These holes were discovered to contain cast skins and dead nymphs. It is said to defoliate trees like mulberry but does not damage crops."

ECOLOGICAL STUDIES ON THE SPOTTED BOLLWORMS OF COTTON AND THEIR PARASITES

II—THE FECUNDITY AND LONGEVITY OF *EARIAS FABIA* AND ITS PARASITE, *MICROBRACON GREENI LEFROYI* UNDER DIFFERENT CONDITIONS OF TEMPERATURE AND HUMIDITY

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CONTENTS

I. INTRODUCTION

In a previous paper (Ahmad & Ghulamullah, 1939), while discussing the pre-imaginal development and viability of *Earias fabia* (Stoll) and *Microbracon greeni lefroyi* (D. & G.) at different temperatures, some of our conclusions were : (*i*) that temperatures between 35°C and 45°C are markedly injurious to the parasite but not to the host, indicating therefore, that the duration for which such temperatures prevail in nature is an important factor determining host and parasite populations, (*ii*) that there seems to be little foundation for the belief that severe winters are more injurious to the parasite than to the host; and (*iii*) that between 16°C and 35°C the parasite develops two to two and a half times faster than its host. With regard to the effect of relative humidity on development it was concluded that, whereas the parasite is highly sensitive to drought, the bollworm is seriously affected by moist conditions. Considering the combined influence of temperature and humidity, rains in summer should cause decrease in the number of the pest by lowering the temperature, which is beneficial to the development of the parasite, and by raising the humidity, which is injurious to the pest. It is a common observation that the incidence of the bollworm is actually low during the monsoon months.

The tentative nature of these conclusions was then emphasised, as they were only based on a study of the development of pre-imaginal stages of the pest and parasite. The other important factors, *viz.*, fecundity, reproductive potential and longevity of adults have been now investigated and the data are presented in this paper.

The material and general methods of work were more or less fully described in our previous work. For studying the fecundity of host, single pairs of freshly emerged moths were liberated in glass tubes and kept at controlled temperatures. Inside the glass tube, a fresh cotton leaf for oviposition and honey solution on cotton wad (in the case of moths to be fed) were provided. Similarly the adult parasites were provided with pieces of *bhindi* (*Hibiscus esculentus*) fruits containing full-grown bollworms for oviposition. The provision of cotton leaf for the former and of *bhindi* fruits containing host larvæ for the parasite was necessary to have normal oviposition. It will be thus noticed that in all these experiments the adults of both the pest and the parasite had to live in a saturated or almost saturated atmosphere. Therefore, the saturation deficiency (S.D.) wherever mentioned refers to the state of moisture during the pre-imaginal period of the species (egg and pupal stages of the host and pupal stage only of the parasite). It will be recalled that larval stages of both the host and parasite must, on account of their contact with moist food, remain necessarily exposed to saturated atmosphere.

It is well known that the conditions prevailing during the pre-imaginal as well as imaginal periods have each a profound influence on the fecundity of the resulting moths, therefore, the effect of environmental conditions prevailing during the two periods are critically and separately discussed. Commencing from freshly-laid eggs of both the host and parasite, large amount of material was reared at constant temperatures of 16°, 20°, 25°, 30° and 35°C and S.D. of 0, 3 and 14 mm. The temperatures at which the entire pre-imaginal life was passed have been, for the sake of brevity, termed hereafter as 'pre-imaginal temperatures', and those prevailing during the adult life as 'imaginal temperatures'. The emerging moths were either allowed to continue to remain at the pre-imaginal temperature (called here constant temperature experiments) or they were transferred to a different temperature soon after emergence (called variable temperature experiments).

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II. The fecundity and oviposition period of *Earias fabia*

The power of multiplication of an insect is largely determined by the rates of its development and mortality on the one hand and its reproductive potential on the other. We have already considered the first two factors (*op. cit.*); we give below data about the fecundity and oviposition of *Earias fabia*, which form basis for determining its reproductive potential.

(*a*) *The pre-oviposition and oviposition periods*

The general habits of the bollworm moths, the nature of oviposition, the mode of egg-laying, etc., have been discussed by Deshpande and Nadkarny (1936) and several other workers. We describe below for the first time our observations on the pre-oviposition, oviposition and post-oviposition periods under different controlled conditions of temperature and humidity.

(*i*) *The pre-oviposition period.*—Deshpande & Nadkarny (*op. cit.*), working in the Bombay Presidency, noted that, whereas some moths began laying eggs on the first night after mating, a great majority of them commenced oviposition about the fourth night. As mating, according to him, took place on the second or third night after the emergence of moths, the pre-oviposition period under Bombay conditions may be taken as three to seven days. A reference to Table I, in which our observations are summarised, will show that the pre-oviposition period, though not very variable, is influenced by environmental conditions prevailing during the pre-imaginal and the adult lives. At constant temperatures (*i.e.*, the

temperature being same during the pre-imaginal and imaginal periods) the pre-oviposition period was 9-10 days at 16°C, 4-6 days at 20°C, 3-3.5 days

TABLE I. *Pre- & post-oviposition periods (in days) of* E. fabia

Temperature °C		S. D.	No. of pairs	Average period of	
Pre-imaginal	Imaginal			Pre-oviposition	Post-oviposition
16	16	3	4	9.8	4
		9	3	10	4
20	20	0	5	5.4	1.2
		3	7	4.4	2.6
		14	7	6.4	3.4
25	25	0	10	3	0.5
		3	10	3.2	1.3
		14	4	3.5	1.5
30	30	0	6	3.3	0.7
		3	8	3.0	0.5
		14	9	3.1	0.4
35	35	0	4	3.0	1.2
		3	2	3.5	1.0
		14	2	3.0	1.0
35	25	0	8	3.1	0.7
		3	6	3.8	1.5
		14	6	3.8	0.5
35	16	0	7	7.0	4.1
		3	7	7.6	2.4
		14	8	8.3	2.0
25	35	0	6	3.1	1.3
		3	6	3.1	0
		14	7	2.8	0.7
25	16	0	5	5.6	0.7
		3	7	5.6	2.0
		14	10	5.9	2.6

at 25°C, 30°C and 35°C. Under variable temperatures (*i.e.*, the temperature being different during the pre-imaginal and imaginal periods) both the pre-imaginal and imaginal temperatures have a share in determining the pre-oviposition period. While at constant temperatures of 25° to 35°C this period was 3-3.5 days, in the case of moths with pre-imaginal period at 25° or 35°C, but adult life at 16°C the pre-oviposition period was prolonged to 6-8 days. It will be also observed that when the difference between pre-imaginal and imaginal temperature was large, (*e.g.*, 35°C and 16°C) the prolongation in pre-oviposition period was more than when the difference between the two temperatures was small (25°C and 16°C).

The condition of atmospheric moisture during the pupal stage seems to have little effect on the duration of the pre-oviposition period, as shown by an examination of the data presented under various S. D. in Table I. For instance, at a temperature of 25°C the pre-oviposition period varied only from 3.0 days at 0 mm. S. D., to 3.5 days at 14 mm. S. D.

(ii) *Time of oviposition.*—It is well known that the bollworm moths lay most of their eggs during the night, especially up to midnight. Deshpande and Nadkarny (*op. cit.*), however, went so far as to state that oviposition does not take place at all during the day time. They further stated, " it was surmised that the absence of light may be one of the requirements for oviposition and, therefore, a few pairs of moths were kept in perfectly dark chambers during the day time. This however did not induce them to lay eggs by day ". This implies that eggs are not laid during the day time whether there is light or not. Our observations on bollworm pairs kept in the incubators show that this is not quite so. In our experiments many females laid a small percentage of eggs during the day time, while some specimens laid quite a fair proportion of eggs during the day. The oviposition record of one such female is shown in Table II. It laid 56 eggs (25 %) during the day time and 169 during the night.

TABLE II. *Number of eggs laid by a moth during different times of the day and night at 24°C*

Time of the day	No. of eggs laid on different days after emergence													Total No. of eggs	Date of	
	1	2	3	4	5	6	7	8	9	10	11	12	13		emergence	death
4 PM-9 AM	—	18	21	7	18	13	14	12	23	13	19	6	6	169	2.xi.38	17.xi.38
12 AM-4 PM	—	8	20	—	—	8	13	—	—	—	—	7	—	56		

(iii) *Distribution of egg-laying.*—Once the female begins to lay eggs she continues to oviposit almost daily. A reference to Table III, wherein the oviposition record of some of the prolific pairs is given, will show that, with very few exceptions, the ' inter-oviposition ' period was less than twenty-four hours. It will be also noticed that the oviposition started with a smaller number of eggs on the first day ; it gradually increased and the maximum number of eggs on a single day was reached usually on the third to fifth day. It again gradually decreased till the female stopped oviposition.

(iv) *Post-oviposition period.*—Oviposition in this species usually continues up to a few days before death. The post-oviposition period, although again depending on temperature (Table I), is much shorter than the pre-oviposition period. It was roughly 4 days at 16°C, 2-3 days at 20°C, 0.5-1.5 days at 25°C and less than a day at 30°C. At 35°C it was again somewhat longer, being a little over twenty-four hours. This is because, as stated later on, 35°C is not suitable for oviposition. If the pre-imaginal and imaginal temperatures are different, it seems both have a share in

TABLE III. *Some typical cases showing oviposition and inter-oviposition periods of* E. fabia *at different temperatures and 3 mm. S. D.*

Temperature °C	No. of typical cases	Date of emergence	Number of eggs laid on different days after emergence (days 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25)	Total No. of eggs	Date of death
16	1	15. vii. 37	— — — — — — — 2 — 6 9 13 3 13 7 4 2 1 5 —	65	11. viii. 37
	2	16. vii. 37	— — — — — — — — — — — — — — 5 — — 1 4 — — — — — —	10	9. viii. 37
	3	10. viii. 37	— — — — — 9 6 12 7 — — — — — — — — — — — — — — —	34	24. viii. 37
20	1	28. ix. 40	— — 2 21 74 25 31 55 31 10 1 20 — — — — — — — — — — —	270	12. x. 40
	2	3. x. 40	— — 62 91 18 32 5 11 — 13 29 17 2 7 — 3 — — — — — — —	290	21. x. 40
	3	7. x. 40	— 10 — 6 1 64 29 22 15 10 15 4 — — — 2 — — — — — — —	178	28. x. 40
25	1	19. x. 38	— — — 25 35 40 23 58 53 49 41 45 30 28 22 — — — — — — — — — —	459	3. xi. 38
	2	17. vii. 38	— — — — 6 10 16 19 18 56 103 14 14 — — — — — — — — — — —	255	31. vii. 38
	3	17. vii. 38	— — 12 1 13 23 78 28 31 8 50 — — — — — — — — — — — — —	251	31. vii. 38
30	1	28. ix. 38	— — 28 33 56 35 32 26 34 32 28 14 15 11 12 4 — — — — — — — — —	360	14. x. 38
	2	27. ix. 38	— — 21 52 25 20 40 52 18 16 19 — — — — — — — — — — — — — —	263	8. x. 38
	3	28. ix. 38	— — — — — 30 52 48 12 42 33 32 25 12 4 1 — — — — — — — — —	291	14. x. 38
35	1	13. xii. 40	— — 82 35 —	117	18. xii. 40
	2	5. xii. 40	— — — 10 —	10	10. xii. 40
	3	11. x. 38	— — — 1 3 4 6 10 6 23 25 — — 15 11 — — — — — — — — — —	104	28. x. 38

determining the post-oviposition period. For instance, while the post-oviposition period at a constant temperature of 25°C was 0.5-1.5 days, in case the moths were transferred from 25°C to 16°C the period was 0.7 to 2.6 days. Likewise, this period at a constant temperature of 35°C was only one day while if the pre-imaginal period was passed at 35°C and the adults were transferred to 16°C the post-oviposition period was prolonged to 2-4 days.

With regard to the effect of moisture, it will be noticed that at 20° and 25°C the post-oviposition period was minimum in a saturated atmosphere and increased with the rise in S. D. *i.e.*, under comparatively dry conditions. At higher temperatures of 30° and 35°C on the other hand, this period was longest in the saturated atmosphere and decreased as the conditions became drier.

(*b*) *The number of eggs laid under different conditions*

Lefroy (1906) considered 60 as the average number of eggs laid by a bollworm female under normal conditions. Deshpande and Nadkarny (*op. cit.*) found the egg-laying capacity to be much higher in Surat, the average number during August-September being 432 eggs per female. They stated that this number declined considerably during December and January due to cold. From this it may appear that temperature during the adult life is the only factor which influences the fecundity of the females. Actually, however, there are a number of other external factors which affect this capacity. As shown by several previous observations *e.g.*, von Linden's (1902) studies on butterflies, and Alpatov and Pearl's (1929) observations on *Drosophila melanogaster*, the temperature and humidity at which the pre-imaginal life and particularly the pupal stage of moths is passed have a profound influence on the longevity and reproductive power of the adults. They are as important as, if not more than, the conditions prevailing during the adult life.

(i) *Influence of constant temperatures.*—A number of moths reared from material kept at 16°, 20°, 25°, 30°, and 35°C were allowed to remain at the same temperatures at which the pre-imaginal life was passed and their fecundity was noted. They were fed on a dilute solution of honey throughout their life. Much though we desired, we found it very difficult to have a fairly large number of observations at the low temperature of 16°C, which is very close to threshold, partly because of the higher mortality among pre-imaginal stages and partly due to the prolonged period of pre-imaginal development extending to about three months. Furthermore, due to protracted development the emergence of moths even from the same batch of eggs was spread out over several days, so that it was difficult to get a sufficient number of moths emerging on the same day to start pairs of the same age. Again, the moths which emerged at 16°C

TABLE IV. *The fecundity of* E. fabia (*fed on honey*) *at different temperatures and saturation deficiencies*

Temperature °C		S.D. 0 mm.			S.D. 3 mm.			S.D. 14 mm.		
			No. of eggs			No. of eggs			No. of eggs	
Pre-imaginal	Imaginal	No. of pairs	Average	Maximum	No. of pairs	Average	Maximum	No. of pairs	Average	Maximum
16	16				4	29.2	65	3	*6	*18
20	20	15	148.9	293	11	136.3	290	15	9.2	51
25	25	10	223	395	11	253	459	12	235.7	508
30	30	14	139	509	9	163	360	11	214	523
35	35	20	6.5	117	17	0.22	11	13	9	104
35	25	15	95.4	306	9	133	474	7	156.7	354
35	16	11	83	240	7	85	106	12	112	248
25	35	16	70	278	12	116	320	7	174	295
25	16	15	117.6	440	7	108	270	10	142	304

* 9 mm. S.D.

were extremely inactive thus reducing the chances of their normal copulation. Therefore, many of these pairs did not lay eggs at all. Out of 22 pairs liberated at 16°C only four pairs under 3 mm. S. D. and three pairs under 9 mm. S. D. laid eggs. The average number of eggs laid by a female at various constant temperatures (under 3 mm. S. D.) of 16°, 20°, 25°, 30° and 35°C were 29, 136, 253, 163 and 0.22 respectively (Table IV). The maximum number of eggs laid per female at the same temperatures were 65, 290, 459, 360 and 11 respectively. Thus, it will be observed that *Earias fabia* lays the largest number of eggs at temperatures between 25° and 30°C. The fecundity decreases as the temperature rises or falls. Beyond 30°C there is a sudden fall in fecundity, so that at 35°C and above, great majority of the moths are sterile. Out of 40 pairs kept for egg-laying at 35°C, 31 did not lay eggs at all.

(ii) *Influence of variable temperatures.*—In this series the immature stages were reared at temperatures of 35°C or 25°C. The moths emerging from the material at 35°C were transferred to 25° or 16°C and those emerging from 25°C were transferred to 35° or 16°C. The fecundity of these moths is given at the bottom of Table IV. It will be noticed that, whereas the fecundity of moths which passed the pre-imaginal as well as imaginal life at 35°C was extremely low, that of moths which had pre-imaginal life at 35°C but were transferred to a favourable temperature of 25°C or 16°C during adult life, was greatly improved. The average number of eggs laid (under 3 mm. S. D.) was 133 when moths were taken from 35° to 25°C and 85 when taken from 35° to 16°C. The corresponding maximum number of eggs per female under the two conditions were 474 and 106. It will be observed that the moths transferred to 25°C laid a much larger number of eggs as compared to those transferred to 16°C. Reverse is the case of moths which had pre-imaginal life at 25°C but were transferred to less favourable temperatures of 35° or 16°C during the adult life. They laid on the average 116 eggs when transferred from 25°C to 35°C and 108 when transferred from 25°C to 16°C (under 3 mm. S. D.) against an average of 253 eggs when both pre-imaginal and imaginal temperatures were 25°C.

It will be clear from this data that the pre-imaginal and imaginal temperatures are almost equally important in determining the fecundity of *E. fabia* moths. It will not be safe to generalise which of the two has a more profound influence, as the effect of change from high to low and from low to high temperatures may not be the same but a comparison of the two sets of observations, *viz.*, fecundity of moths transferred from 35°C to 25°C and of those transferred from 25° to 35°C, seems to show that the imaginal temperature has probably a little more share in influencing the fecundity.

(iii) *Influence of humidity.*—The data on the fecundity of moths with pre-imaginal periods (egg and pupal stages) under the different saturation

deficiencies, *viz.*, 0 mm., 3 mm. and 14 mm. are presented in Table IV. At 16°C and 35°C the number of pairs was too small to admit of a reliable comparison. At 20°C there was little difference in the fecundity under 0 mm. and 3 mm. S. D., but under 14 mm. S. D. the fecundity was distinctly lowered. At 25° and 30°C, which is the most optimum range of temperature, a saturated atmosphere is distinctly injurious and the fecundity of moths is markedly lowered. The average number of eggs per female was highest under 3 mm. S. D. at 25°C and under 14 mm. S. D. at 30°C. The maximum number of eggs laid by a female was highest under 14 mm. S. D. at both the temperatures (508 eggs at 25°C and 523 at 30°C). Likewise at all the variable temperatures tried the average fecundity was generally minimum under saturated conditions and maximum under a dry condition of 14 mm. S. D.

(iv) *Influence of feeding.*—In all the experiments on fecundity referred to above the moths were fed on a dilute solution of honey throughout their life. A few experiments were separately carried out to study the fecundity of moths without feeding, and thus distinguish the effect of feeding on the number of eggs laid. The results are given in Table V. It will be observed

TABLE V. *The fecundity of fed and unfed pairs of* E. fabia *at some temperatures and S. D.*

Temperature °C		S.D. mm.	No. of eggs laid by fed pairs		No. of eggs laid by unfed pairs	
Pre-imaginal	Imaginal		Average	Maximum	Average	Maximum
25	25	3	253	459	92	409
25	35	3	116	320	5	23
25	16	3	108	270	34	78
25	25	14	235.7	508	33	91
25	35	14	174	295	3	15
25	16	14	142	304	20	51

that moths fed on honey solution laid a markedly higher number of eggs than those not fed. For instance, at a constant temperature of 25°C the fed pairs laid on the average 253 (3 mm. S. D.) and 236 (14 mm. S. D.) eggs, while the unfed pairs laid 92 and 33 eggs respectively. The maximum number of eggs per female was also much higher in the case of fed moths than the unfed ones. It is also interesting to note that of the two saturation deficiencies tried, the higher one (dry condition during pupal stage) is generally favourable to the fed moths and the lower one (moist condition) is distinctly favourable to the unfed moths.

TABLE VI. *The effective reproductive potential of* E. fabia *under different conditions*

Temperature °C		S. D, m.m.	Average No. of eggs per female	% viability of eggs	No. of larvæ hatched	% larval viability	No. of pupæ formed	% pupal viability	No. of moths obtained	Effective reproductive potential*
Pre-imaginal	Imaginal									
16	16	3	29.2	82	23.9	13.3	3.2	62.6	2	1
		9	6	80	4.8	,,	0.64	—	—	—
20	20	0	148.9	70.7	105.3	12.9	13.6	73.8	10	5
		3	136.5	88.9	121.3	,,	15.6	79.6	12.4	6.2
		14	9.2	84.9	7.7	,,	0.99	—	—	—
25	25	0	223	92.2	205.6	11.1	22.8	77.6	17.7	8.8
		3	253	87.2	220.6	,,	24.5	78.0	19.1	9.5
		14	235.7	89.6	211.2	,,	23.4	69.4	16.2	8.1
30	30	0	139	93.3	129.7	13.7	17.8	82.9	14.8	7.4
		3	163	96.0	156.5	,,	21.4	80.8	17.3	8.6
		14	214	93.7	200.5	,,	27.5	78.0	21.4	10.7
35	35	0	6.5	92.9	6.00	12.1	0.7	—	—	—
		3	0.22	95.3	—	,,	—	—	—	—
		14	9	66.4	6.0	,,	0.7	—	—	—
35	25	0	95.4	92.2	88	11.1	9.8	77.6	7.6	3.8
		3	133	87.2	116	,,	12.9	78.0	10.0	5.0
		14	156.7	89.2	140	,,	15.5	69.4	10.8	5.4
35	16	0	83	73.7	61	13.3	8.1	62.6	5.0	2.5
		3	85	82.0	70	,,	9.3	71.1	6.6	3.3
		14	106	80.0	85	,,	11.3	54.5	6.2	3.1
25	35	0	70	92.9	65	12.1	7.8	73.1	5.7	2.8
		3	116	95.3	110.5	,,	13.4	72.9	9.8	4.9
		14	174	66.4	115.5	,,	13.9	69-2	9.6	4.8
25	16	0	117.6	73.7	86.7	13.3	11.5	62.6	7.2	3.6
		3	108	82.0	88.5	,,	11.8	71.1	8.4	4.2
		14	142	80.0	113.6	,,	15.1	54.5	8.2	4.1

* Sex ratio of 50 : 50 has been assigned in this calculation

(c) *The reproductive potential*

The effective reproductive potential of *E. fabia* under different conditions of temperature and S. D. is shown in Table VI. Figures for egg, larval and pupal viabilities are reproduced from our previous paper (*op. cit.*). It will be observed that owing to high larval mortality noticed under laboratory conditions, the effective reproductive potential was generally low. The maximum reproductive potential (10.7) was obtained at a temperature of 30°C and S. D. of 14 mm., the next best conditions being 25°C and 3 mm. S. D. Thus temperatures between 25° and 30°C and S. D. between 3 and 14 mm. afford the most optimum conditions for the reproduction of this species. At a constant temperature of 35°C whatever the S. D., the population of the species went on decreasing; therefore, it would not be able to exist for a very long time under these conditions. It would also become practically extinct at a constant temperature of 20°C if the S. D. was 14 mm. and at a temperature of 16°C if the S. D. was 9 mm. Under 3 mm. S. D. at 16°C the species could barely maintain its existing population without being able to increase.

III. THE LONGEVITY OF ADULTS OF *Earias fabia*

Previous observations on the longevity of moths show a great amount of variation, naturally because of the different environmental conditions under which the observations were taken. Deshpande and Nadkarny (*op. cit.*) state that the average life of a moth fed on honey or sugar solution was found to vary from 8 to 22 days, a few lived up to 30 days and one lived as long as 34 days. Obviously the longevity depends on several factors such as the prevailing temperature and humidity, quality and quantity of food available, etc., some of which are discussed below :—

(a) *Influence of temperature*

Temperature is by far the most important factor regulating the longevity of adults just as it does the development of immature stages. Generally speaking, moths are short lived at high temperatures and have a longer life at low temperatures within the optimum range (Table VII). The effect of same and different pre-imaginal and imaginal temperatures may be considered separately.

(i) *Influence of constant temperature*.—When the pre-imaginal and imaginal periods were passed at the same temperature, the average longevity of copulating pairs fed on honey solution at different temperatures of 16°, 20°, 25°, 30°, and 35°C (under 3 mm. S. D.) was 20, 16.9, 16, 12.4 and 5.7 days respectively. The maximum duration of life under these conditions was 26, 31, 37, 26 and 24, days. This would indicate that although the average longevity decreased considerably with the rise of tem-

TABLE VII. *The longevity (in days) of copulating pairs of* E. fabia *(fed on honey) at different temperatures and S. D.*

Temperature °C		S.D. 0 mm.					S.D. 3 mm.					S.D. 14 mm.				
					Av. longevity of sexes					Av. longevity of sexes					Av. longevity of sexes	
Pre-imaginal	Imaginal	No. of moths	Average longevity	Maximum longevity	Males	Females	No. of moths	Average longevity	Maximum longevity	Males	Females	No. of moths	Average longevity	Maximum longevity	Males	Females
16	16	13	20.2	26	20.3	20.2	6	20	26	20	20	4	12	19	11	12
20	20	31	18.1	30	17.2	19.0	12	16.9	31	15.3	18.5	16	10.2	15	9.9	10.4
25	25	21	12.1	22	10.8	13.4	30	16	37	15.0	16.2	24	14.1	22	13	16.3
30	30	24	10.9	19	10.1	11.6	18	12.4	26	11	13.3	22	11.7	23	11.2	12.2
35	35	31	4.4	15	4.3	4.8	26	5.7	24	4.3	7	24	11	20	10	12.0
35	25	14	12.6	16.6	11.6	13.6	21	15.6	29.5	12.3	19.1	14	16.9	18.8	15	18.8
35	16	21	26.9	30.7	22.8	30.7	37	21.4	45.4	22	21.0	22	37	38.2	38.2	51.5
25	35	25	11.8	13.8	10.1	13.8	29	11.4	21.4	9	13.9	14	13.2	24	15	11.4
25	16	27	28.0	55.4	24.8	32.1	29	30.8	46.6	31.4	30.5	20	32.3	42	32.9	31.7

perature, a few individuals lived fairly long even at high temperatures (see maximum figures). Again, a comparison of the longevity of the two sexes will show that females were generally longer lived than the males. At various constant temperatures mentioned above (under 3 mm. S. D.) the average longevity of the copulated female moths was 20, 18.5, 16.2, 13.3 and 7 days respectively against 20, 15.3, 15.0, 11 and 4.3 days in the males.

(ii) *Influence of variable temperatures.*—In this series, moths emerging from material at 35°C were kept at 25° or 16°C during the adult life and those emerging from 25°C were kept at 35° or 16°C during the adult life. From Table VII it will be observed that while at a continuous temperature of 35°C the longevity was very short, being only 5.7 days (under 3 mm. S. D.), moths with pre-imaginal life at 35°C and adult life at 25°C or 16°C lived as long as 15.6 and 21.4 days (under 3 mm. S. D.) respectively. Here again the life at 16°C was longer than at 25°C. The longevity of moths transferred from 25° to 35°C was 11.4 days against 16 days at a continuous temperature of 25°C. A comparison of the longevity under the two experiments, *viz.*, 35°C to 25°C and 25°C to 35°C reveals a longer life in the former case. This indicates that a temperature of 35°C during the adult life is more injurious than that during the pre-imaginal period. It is interesting to find that the longevity of moths transferred from 25°C to 16°C (30.8 days) was longer than that at a continuous temperature of 25°C or 16°C. This would indicate that the adult stage is more resistant to low temperatures than the pre-imaginal stages. Under laboratory conditions it was noticed that if all the pre-imaginal stages were passed at a low temperature of 16°C, the resulting moths almost always showed some degree of malformation, mostly in wings and sometimes in legs and other body parts. As a result of this injurious effect, these adults when kept at 16°C lived a shorter life than those emerging from material at 25°C, and thereafter kept at 16°C. In other words, a temperature of 16°C during the adult period lengthens the life but during the pre-imaginal period it is injurious, as it causes malformation in the organs of the adult. Maximum adult life will be obtained if the pre-imaginal stages are passed at 20° to 25°C and the adult stage is exposed to temperatures round about 16°C or possibly even less. These are exactly the conditions which moths of the last brood have to face in nature. Their pre-imaginal stages are passed at favourable temperatures of 20°C or so during October and November and the adults have to face the rigours of cold climate during December and January. Under these conditions the average adult life is easily over a month and the maximum well over one and a half months.

(*b*) *Influence of humidity*

The effect of the saturation deficiency prevailing during the pre-imaginal period on the longevity of resulting adults will be clear from a

reference to Table VII. Adults emerging from material kept under 3 mm. S. D. were generally the longest lived, those reared at 0 mm. S. D. come next, while adults from material undergoing very dry conditions (14 mm. S. D.) had the shortest life. Under variable temperatures, the adults from material kept at 0 mm. S. D. lived the shortest, while those from pre-imaginal stages under dry conditions lived the longest life. Thus within certain limitations a lower humidity during the pre-imaginal period is favourable to the longevity of adults.

(*c*) *Influence of food*

Feeding of moths on honey or sugar solution decidedly prolongs their life. This is borne out by the data presented in Table VIII. At 25°C and S. D. of 3 mm. and 14 mm. the average longevity of fed moths was 16.0 and 14.1 days while that of unfed moths was only 8.0 and 9.1 days. The maximum duration of life under these conditions was 37 and

TABLE VIII *The longevity (in days) of fed and unfed pairs of* E. fabia *at some temperatures and S. D.*

Temperature °C		S. D. mm.	Longevity of moths fed on honey		Longevity of unfed moths	
Pre-imaginal	Imaginal		Average	Maximum	Average	Maximum
25	25	3	16.0	37	8.0	21
		14	14.1	22	9.1	14
25	35	3	11.4	21.4	2.9	4
		14	13.2	24.0	3.4	5
25	16	3	30.8	46.6	15.0	23
		14	32.3	42.0	15.2	36

22 days in the case of fed moths and 21 and 14 days in the case of unfed moths. The same is true at variable temperatures. In nature, the food of moths in the form of nectar of flowers is almost always available, more so during the active period of the bollworm and thus helps to give longer life to the moths.

(*d*) *Influence of copulation*

Detailed observations on the longevity of copulating pairs have been discussed above. Data on the longevity of uncopulated pairs under some conditions of temperature and humidity are given in Table IX. A

TABLE IX. *The longevity (in days) of uncopulated* E. fabia *moths (fed on honey) at different temperatures and S. D.*

Temperature °C		S. D. 0 mm.					S. D. 3 mm.					S. D. 14 mm.				
Pre-imaginal	Imaginal	No. of moths	Average longevity	Maximum longevity	Av. longevity of sexes		No. of moths	Average longevity	Maximum longevity	Av. longevity of sexes		No. of moths	Average longevity	Maximum longevity	Av. longevity of sexes	
					Males	Fe-males				Males	Fe-males				Males	Fe-males
16	16	31	12.8	19	12.1	13.8	7	16.6	31	16.6	—	15	10	18	10.1	10
25	25	23	8.8	19	7.3	9.2	28	7	13	—	7	23	12.3	30	8.6	18.2
30	30	17	5.7	23	4.0	11.5	—	—	—	—	—	10	11.4	34	8.0	16.5
35	35	13	4.6	9	—	4.6	9	3.2	9	3.2	—	17	6.5	19	3.2	7.5
35	25	16	15.5	28.5	12.9	20	18	16.1	36.5	14.3	19.1	18	20.3	32.6	19.6	22.6
35	16	14	29.8	54.6	30.0	29.4	14	29.7	46.6	29.0	30.4	21	32.5	57.5	28.8	36.0
25	35	14	11.4	20.5	9.3	13.5	15	11.7	22.5	10.7	13.7	19	12.7	24.0	12.9	12.6
25	16	23	33.2	84.4	27.7	38.4	23	34.3	60.6	33.5	35	6	36.8	53	34.5	38

comparison of these figures with those in Table VII will show that under variable temperatures the uncopulated moths usually lived longer than those allowed to copulate. It is curious, however, that under constant temperature experiments the moths not allowed to copulate lived a shorter life than those allowed to copulate. For instance under 0 mm. S. D. and at temperatures of 16°, 25°, 30° and 35°C the uncopulated moths lived 12.8, 8.8, 5.7 and 4.6 days against 20.2, 12.1, 10.9 and 4.4 days in the case of copulated moths. It may be mentioned that in nature variable temperatures are more common than a uniform temperature throughout the pre-imaginal and imaginal periods.

IV. The fecundity and oviposition period of *Microbracon greeni lefroyi*

The data hitherto recorded in literature regarding the oviposition and number of eggs laid by *Microbracon greeni lefroyi* are much more variable and meagre as compared to those relating to the host. The value of such data is further reduced by the fact that the conditions under which they were recorded are in many cases not accurately mentioned. Our data on the oviposition period and the fecundity of *Microbracon greeni lefroyi* under different controlled conditions, are presented below, and discussed in the light of those as are available so far.

(*a*) *The pre-oviposition, oviposition and post-oviposition periods*

(*i*) *The pre-oviposition period*.—As a result of experiments carried out in the Bombay Presidency, Deshpande and Nadkarny (*op. cit.*) concluded that no eggs are laid by the parasite on the day of its emergence and frequently a week or more elapses before oviposition commences under laboratory conditions. The environmental conditions under which the above observations were made are, however, not stated. The authors further add that normally oviposition begins on the second or third day after emergence of the female.

An examination of our data on pre-oviposition period presented in Table X will show that this period is influenced by the conditions prevailing during the pre-imaginal and imaginal periods of the parasite. At constant temperatures of 16°, 20°, 25° and 30° C the average pre-oviposition periods were 8.2-10.1, 3.0-3.3, 2.2-2.4 and 2.4-3.8 days respectively. The influence of S. D. prevailing during the pre-imaginal (pupal) period is also significant. Adults reared from pupæ under saturated conditions (S.D., 0 mm.) generally matured and laid eggs quicker than those reared under dry conditions. Thus at 16° C, the pre-oviposition period was 8.2 days under 0 mm. S.D., against 10.1 days under 9 mm. S.D.; likewise at 20°C, it was 3.0 days under 0 mm. S.D., against

TABLE X. *Pre-oviposition & post-oviposition periods (in days) of* M. greeni lefroyi

Temperature °C		S. D. (mm.)	No. of pairs	Average period of	
Pre-imaginal	Imaginal			Pre-oviposition	Post-oviposition
16	16	0	12	8.2	4.3
20	20	9	11	10.1	5.6
		0	14	3.0	1.5
		3	7	3.3	2.0
25	25	14	6	3.3	2.0
		0	12	2.2	1.1
		3	25	2.3	1.3
30	30	14	9	2.4	1.3
		0	10	3.8	1.0
		3	12	3.3	1.2
35	35	14	10	2.4	1.3
25	35	No eggs laid at the three S. Ds. tried			
		0	7	3	1.5
		3	6	2.6	1.4
25	16	14	6	2.5	1.5
		0	8	7.5	9.1
		3	6	7.5	8.0
16	25	14	9	7.0	16.0
		0	8	5.0	2.0
		3	10	2.4	2.5
		9	6	3.1	4.0

3·3 days under 3 mm. S.D., and so on. At 30°C, however, the pre-oviposition period was shorter under dry conditions as compared to saturated atmosphere.

The two experiments on the influence of variable temperatures, *viz.*, adults transferred from 25°C, to 16°C and *vice versa* seem to show that in the case of *M. greeni lefroyi*, the temperature during the adult life has more marked influence on the pre-oviposition period than the temperature during the pre-imaginal development. Thus, the adults transferred from 25°C to 16°C commenced egg-laying after 7-7·5 days while those transferred from 16°C to 25°C did so after 2.4 to 5.0 days only.

(*ii*) *Distribution of egg-laying*.—The oviposition record of some females at different temperatures is given in Table XI. At 16°C, the oviposition was very irregular, there being usually an inter-oviposition period of 1-3 days which sometimes extended to 5 days. At 20°c, with the exception of a few interruptions of 24 hours or more, the oviposition usually took place every day. In rare cases (pair No.3) there were longer interruptions of 2-12 days. Furthermore, the oviposition started usually with less number of eggs and the maximum was reached some days later. At 25°C, the inter-oviposition period was less than 24 hours. As the total number of eggs laid by a female is the largest at this temperature and the oviposition period is also comparatively short, the number of eggs

TABLE XI. *Some typical cases showing oviposition and inter-oviposition periods of* M. greeni lefroyi *at different temperatures & 3 mm. S. D.*

Temperature °C	No. of typical cases	Date of emergence	Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total No. of eggs	Date of death
16	1	22.7.37	July																												—	—	—	—		
			Aug.	—	—	—	—	—	—	1	—	1	—	3	—	3	—	—	—	—	—	3	4	—	—	—	2	—	—	—	—	—	6	3		
			Sept.	6	—																															
	2	3.8.37	Aug.				—	—	—	—	—	—	—	—	8	—	—	—	—	3	—	2	—	—	—	3	3								32	2. 9. 37
	3	14.9.37	Sept.															—	—	—	—	—	—	—	—	—	—	—	4	7	—	5	—	5	19	24. 8. 37
			Oct.	—	—	2	1	—	2	—	6	—	—	—	4	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—					39	27. 10. 37
20	1	12.7.39	July													—	—	—	—	1	—	13	6	14	3	10	3	2							52	25. 7. 39
	2	14.7.39	July															—	—	1	—	6	6	5	5	10	4	9	10	8	—	10	5	8		
			Aug.	12	—	3	15	5	—	6	—	—																							138	9. 8. 39
	3	5.8.39	Aug.						—	—	—	1	1	1	9	—	7	—	5	—	7	8	—	1	14	—	—	3	—	—	10	—	—	3		
			Sept.	—	2	—	—	7	—	6	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2	—	—	—	3	2	—				94	28. 9. 39
25	1	22.4.38	April																							—	—	—	—	1	4	7	—	5		
			May	7	4	6	4	8	4	5	6	2	8	2	—	6	4	—																	83	17. 5. 38
	2*	15.7.38	July																—	5	16	16	15	16	5	13	18	20	6	—	—				130	28. 7. 38
	3	14.1.39	Jan.															—	5	8	27	15	5	19	9	6	10	7	4	5	—	7	10	—		
			Feb.	8	—																														145	3. 2. 39
30	1	5.4.41	April						—	—	7	6	4	3	7	5	5	5	3	2	7	3	4	4	3	—	—	—							68	26. 4. 41
	2	5.4.41	April						—	4	6	6	6	—	5	—	1	4	5	8	3	5	3	5	3	6	5	3	6	6					90	28. 4. 41
	3	5.4.41	April						—	—	—	4	5	4	4	—	7	8	7	5	—	6	3	—	3	—	4	7	10	12	7	3	8	2		
			May	3	—	—	—																												112	5. 5. 41

The columns 1–31 give the number of eggs laid on different dates after emergence.

* Oviposition mostly on pink bollworm larvæ

laid per day is larger than that at any other temperature. A maximum of 27 eggs during 24 hours was recorded at 25°C.

(*iii*) *The post-oviposition period.*—An examination of Table X, wherein the post-oviposition period under different conditions is presented, will show that on the average this period was 4.3-5.6 days at 16°C, 1.5-2.0 days at 20°C and 1.0-1.3 days at 25°C to 30°C. In the variable temperature experiments, when the adults reared at 25°C were transferred to 16°C the post-oviposition life was 8-16 days, but when transferred from 16°C to 25°C it was only 2.0 to 4.0 days. Here again, the imaginal temperatures seem to have more profound influence on the post-oviposition period than the pre-imaginal temperatures. It will be further observed that the post-oviposition period was somewhat shorter in the case of adults reared from pupæ kept under saturated conditions than those with pre-imaginal life under drier conditions.

(*b*) *The number of eggs laid under different conditions*

Deshpande and Nadkarny (*op. cit.*) recorded the number of eggs laid by the parasite only in a few cases, because, according to them, the counting involved disturbance of the eggs with injurious effect. We are not able to appreciate this difficulty as we have recorded the eggs in all the experiments without injuring them in any way. From their limited observations, the above mentioned authors recorded 16-84 eggs per female in the case of parasites obtained from Khandesh and 95-504 eggs per female in the case of those collected locally at Surat. They, however, gave more data about the adult progeny emerging from parents collected from different sources. Thus the parasites collected from Khandesh yielded a progeny of 4-58 adults per pair, those from the Punjab yielded 5-128 adults and those collected locally at Surat gave 4-136 adults. Without analysing the influence of various environmental conditions, on the fecundity of the parasites from different sources, the authors leave the data with the remarks " there is a great variation in the number of adults obtained from each pair which is probably due to the susceptibility of the parasite to the unnatural conditions of breeding in captivity". Husain and Mathur (1921, 1923), working in the Punjab, recorded a maximum number of 216 eggs by a parasite.

Our observations on the number of eggs laid by the parasite under different conditions are discussed below :

(*i*) *Influence of temperature.*—The adult parasites emerging from immature stages reared at constant temperatures of 16°, 20°, 25°, 30° and 35°C were either allowed to continue to remain at the temperature at which the pre-imaginal life was passed or transferred to a different temperature. They were fed on a dilute solution of honey and their fecundity

is recorded in Table XII. In the first series (same temperature during preimaginal and imaginal life) it will be noticed that the number of eggs laid

TABLE XII. *The fecundity of* M. greeni lefroyi (*fed on honey*) *at different temperatures and saturation deficiencies*

Temperature °C		S.D. 0 mm.			S.D. 3 mm.			S.D. 14 mm.		
Pre-imaginal	Imaginal	No. of pairs	No. of eggs: Average	No. of eggs: Maximum	No. of pairs	No. of eggs: Average	No. of eggs: Maximum	No. of pairs	No. of eggs: Average	No. of eggs: Maximum
16	16	12	18.2	39	—	—	—	*11	*14.5	*38
20	20	8	29.1	40	7	55.4	138	14	53.5	134
25	25	12	66	102	21	67	145	9	31.2	62
30	30	10	54.6	121	12	55	112	6	23	40
35	35	11	—	—	15	—	—	—	—	—
25	35	20	9.5	54	7	10	23	13	7.6	63
25	16	8	50.5	78	12	69.5	159	16	26	33
16	25	12	29	72	10	50.9	129	—	—	—

*These observations were taken at 9 mm. S. D. instead of 14 mm. S. D.

per female rose with the rise in temperature up to 25°C and thereafter it declined, the average figures (under 0 mm. S.D.) being 18 eggs at 16°C, 29 eggs at 20°C, 66 eggs at 25°C and 54 eggs at 30°C. The corresponding maximum figures were 39, 40, 102 and 121 eggs per female. At 35°C a large number of pairs were kept for oviposition but all died without laying any eggs at all. A temperature of 25°C seems to be the most optimum for fecundity.

In the second series the adults emerging from material reared at 25°C were transferred to 35°C or 16°C. Those transferred to 35°C did not lay eggs in the majority of cases. The average of a few females which laid eggs was 9.5 eggs, 10 eggs, and 7.6 eggs under 0, 3 and 14 mm. S.D. respectively. It will be thus observed that most of the adults with pre-imaginal development under an optimum temperature of 25°C became sterile when transferred to 35°C during the imaginal life. The other lot transferred from 25° to 16°C laid a good number of eggs, the average per female being 50.5 eggs and 69.5 eggs under 0 mm. and 3 mm. S.D. respectively. The corresponding maximum number of eggs per female was 78 and 159. Adults reared at 16°C and transferred to 25°C laid fairly good number of eggs, but less than those transferred from 25° to 16°C, the average being 29 and 50.9 and the maximum 72 and 129 eggs under 0 mm. and 3 mm. S. D. respectively.

(*ii*) *Influence of relative humidity of air.*—The data on the fecundity of adults with pupal period passed under different saturation deficiencies,

viz., 0 mm., 3 mm. and 14 mm. are presented in Table XII. At 20° C, there was little difference in the fecundity under 3 mm. and 14 mm. S.D., but under 0 mm. S.D., the fecundity was distinctly lowered. At 25° and 30°C, a dry atmosphere (14 mm. S.D.) was distinctly injurious and the fecundity was lowered. There was very little difference in fecundity under 0 and 3 mm. S.D. at these two temperatures. The average and maximum number of eggs laid by a female was highest under 3 mm. S.D. at 25°c. In the second series (variable temperature experiments) also, 3 mm. S.D. was the most optimum humidity and 14 mm. S.D. was more injurious than 0 mm. S.D.

(*iii*) *Influence of feeding.*—The fecundity of fed and unfed parasites at temperatures of 20° and 25°C and saturation deficiencies of 0 mm. and 3 mm. is given side by side in Table XIII for comparison. Whereas the fed females laid on the average 29.1 and 55.4 eggs at 20°c and 66.0

TABLE XIII. *The fecundity of fed and unfed pairs of* M. greeni lefroyi *at some temperatures and S. D.*

Temperature °C		S. D. mm.	No. of eggs laid by fed pairs		No. of eggs laid by unfed pairs	
Pre-imaginal	Imaginal		Average	Maximum	Average	Maximum
20	20	0	29.1	40	14.4	26
20	20	3	55.4	138	22.42	27
25	25	0	66.0	102	15.0	26
25	25	3	67.0	145	23.8	52
25	35	0	9.5	54	nil	nil
25	35	3	10	23	nil	nil
25	16	0	50.5	78	20.0	49
25	16	3	69.5	159	23.5	36

and 67.0 eggs at 25°C under the two conditions of saturation deficiencies, those which were not fed laid 14.4 and 22.4 eggs at 20°C and 15.0 and 23.8 eggs at 25°C. It is obvious, therefore, that the fecundity of the females is increased by feeding, the difference being more marked at 25°C than at 20°C. This is natural because the necessity to make up for loss of water and energy by feeding is more marked at higher temperatures than at low temperatures. In nature it may be assumed that nectar of flowers is usually available for feeding and it is very rare that starvation takes place.

TABLE XIV. *The fecundity of uncopulated females of* M. greeni lefroyi *fed on honey solution*

Temperature °C		S. D. mm.	No. of eggs laid per female	
Pre-imaginal	Imaginal		Average.	Maximum
20	20	0	18.55	42
25	25	0	12.5	27
20	20	3	20.8	59
25	25	3	14.7	69

(*iv*) *Influence of copulation*.—It is well known that *M. greeni lefroyi* females lay eggs without copulating also, but the resulting progeny consists entirely of males. This is sometimes very helpful for the existence of the species, particularly when the females are pre-ponderant. They lay eggs without copulating and usually live long enough for the males emerging from their own progeny to be ready for normal reproduction.

The number of eggs laid by females fed on honey but not allowed to copulate is much less than (Table XIV) those having normal copulation. The virgin females laid only 18.5 and 20.8 eggs at 20°C and 12.5 and 14.7 eggs at 25°C (under 0 mm. and 3 mm. S.D. respectively) against 29.1 and 55.4 eggs at 20°C and 66 and 67 eggs at 25°C laid by the couplated females.

(*c*) *The oviposition record of an exceptional pair*

An examination of Table XII, in which results of experiments on the fecundity of the parasite at various constant and variable temperatures under different S.D. are presented, shows that the maximum number of eggs laid by a parasite under these conditions was 159. A few pairs reared from material at 25°C and 14 mm. S.D. were transferred to 20°C during adult life and the number of eggs laid by them was noted. All these pairs were supplied with prepupæ of *Earias* spp. for oviposition. One of these pairs, which emerged on 31st of August 1940, laid an exceptionally large number of eggs as shown in Table XV. It will be seen that the female started laying eggs on 7-ix-1940 and continued to do so during the five months from September to January 1941. It laid a total number of 589 eggs and lived for 168 days, thereby setting up a record both for oviposition and longevity. During the course of the life of the female 12 males were supplied. This indicates the maximum capacity of the parasite for egg-laying, which manifests itself under most favourable conditions of

TABLE XV. *Oviposition record of an exceptional pair of* M. greeni lefroyi *at* 20° *C.*
(Pre-imaginal life at 25°C & 14 mm. S.D. Date of emergence—31st August 1940)

Month	Number of eggs laid on different dates after emergence																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
September	—	—	—	—	—	—	14	—	4	—	10	8	—	4	—	20	7	17	6	7	3	2	—	—	4	11	—	10	—	14	
October	10	6	6	—	—	—	—	—	—	7	10	12	—	16	4	—	13	—	2	7	9	5	8	12	—	9	6	5	6	7	4
November	13	—	9	23	8	9	—	—	—	6	8	7	2	—	6	6	—	12	—	21	—	5	—	—	20	3	4	2	5	2	
December	3	2	5	—	4	—	3	—	7	—	6	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	—	8
January	4	2	—	5	—	—	—	1	—	4	—	2	2	—	5	—	8	1	2	—	4	—	—	9	4	—	7	—	2	3	—
February	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Died															

Remarks :—1. 12 males were supplied during the life of the female
2. Total number of eggs laid by the female is 589 during a life of 168 days

temperature, humidity, food, etc. This experiment also shows the possibility of females emerging in nature in September and October being able to successfully live upto February and March, when the host again becomes active after winter.

It is also noteworthy that this female laid all its eggs on prepupæ of *Earias* spp. enclosed in their silken cocoons.

(*d*) *The reproductive potential*

The effective reproductive potential of *M. greeni lefroyi* under different conditions of temperature and humidity is shown in Table XVI. Figures for viabilities of the various immature stages are reproduced from our previous paper (*op. cit.*). It will be observed that the maximum reproductive potential (21.5) was obtained when the individuals passed their pre-imaginal life at 25°C and 3 mm. S.D. and were then transferred to 16°C during the adult life. At a constant temperature of 25°C, the reproductive potential was almost the same 21 under 0 mm. and 3 mm. S.D. A.S.D. of 14 mm. even at the optimum temperature of 25°C markedly lowered the reproductive potential (3.7). At 30°C, the reproductive potential was fairly high, being 17.3 and 14.5 under 0 mm. and 3 mm. S.D, respectively. It is further clear that the species could not exist at a constant temperature of 35°C. The reproductive potential was lowest when the adults reared at 25°C were transferred to 35°C. The species could maintain its existence if the pre-imaginal development was under 0 mm. and 3 mm. S.D. but would soon become extinct under 14 mm. S.D. The reproductive potential at 16°C was 4.25 and 3, under 0 mm. and 9 mm. S.D. respectively. Thus low temperatures are far less injurious to the parasite than high temperatures.

V. THE LONGEVITY OF *Microbracon greeni lefroyi* ADULTS

The average life of an adult under Surat (Bombay) conditions was recorded by Deshpande and Nadkarny to be 11-31 days and the maximum life as much as two months during winter. These authors also performed some experiments on longevity under roughly controlled conditions of temperature and found that the average life of the adults fed on honey solution was 44 days at 48°-54°F, 38 days at 60°-64°F., 31 days at 64°-68°F., and 14 days at 70°-76°F. In these experiments the humidity was not controlled and environmental conditions which prevailed during the pre-imaginal life of these adults are not mentioned. In our experiments both the temperature and humidity were controlled and adults with pre-imaginal life under known conditions of environment were used.

TABLE XVI. *The effective reproductive potential of* M. greeni lefroyi *under different conditions*

Temperature °C Pre-imaginal	Temperature °C Imaginal	S.D. mm.	Average No. of eggs per female	% viability of eggs	No. of larvæ hatched	% larval viability	No. of pupæ formed	% pupal viability	No. of adults obtained	*Effective reproductive potential
16	16	0	18.2	95	17.3	59	10.2	83.7	8.5	4.25
		9	14.5	,,	13.8	,,	8.1	73.7	6	3
20	20	0	29.1	94	27.4	62.3	17.0	94.9	16.1	8.05
		3	55.4	,,	52.0	,,	32.4	94.9	30.7	15.35
		14	53.5	,,	50.1	,,	31.2	72	22.5	11.25
25	25	0	66	95.3	63	73.6	46.4	88.8	41.2	20.6
		3	67	,,	64	,,	47.1	88.1	41.5	20.75
		14	31.2	,,	29.7	,,	21.9	34	7.4	3.7
30	30	0	54.6	99.2	54.2	75.4	41	84.4	34.6	17.3
		3	55	,,	54.6	,,	41	70.6	29	14.5
		14	23	,	22	,,	16.6	75	12.4	6.2
25	35	0	9.5	95.3	9	73.6	6.6	88.8	5.8	2.9
		3	10	,,	9.5	,,	7	88.1	6.2	3.1
		14	7.6	,,	7.2	,,	5.3	34	1.8	0.9
25	16	0	50.5	95.3	48.1	73.6	34.4	88.8	30.5	15.25
		3	69.5	,,	66.2	,,	48.7	88.1	43	21.5
		14	26	,,	24.8	,,	18.3	34	6.2	3.1
16	25	0	29	95	27.5	59	16.2	83.7	13.6	6.8
		3	50.9	,,	48.4	,,	28.6	73.7	21	10.5

*Sex ratio of 50 : 50 has been assumed in this calculation

(a) *Influence of temperature*

In order to distinguish between the effect of pre-imaginal and imaginal temperatures on the longevity of adults, the results of experiments under constant and variable temperatures are discussed separately.

(*i*) *Influence of constant temperatures.*—The average longevity of copulating adults fed on honey solution which passed their pre-imaginal and imaginal periods at the same temperatures of 16°, 20°, 25°, 30° and 35°C (under 0 mm. S.D.) was 44.2, 15, 14.2, 13.6 and 2.8 days (Table XVII). The maximum duration of life under these conditions was 72, 38, 31, 27 and 4 days respectively. From these figures it will be observed that while a low temperature of 16°C was extremely favourable for adult life, a high temperature of 35°C was markedly injurious. Between 20° to 30°C both the average and maximum figures show little variation. An examination of the longevity of the two sexes shows that the females invariably lived longer than the males at all the temperatures tried. Thus at constant temperatures of 16°, 20°, 25°, 30° and 35°C (under 0 mm. S.D.), the females lived an average life of 55, 17.3, 15.2, 15.0 and 3 days respectively against males with an average life of 33.5, 13.2, 11.5, 11.0 and 2.7 days under the same conditions.

(*ii*) *Influence of variable temperatures.*—In these experiments adults emerging from material reared at 25°C were transferred to 16° or 35°C and those reared from material at 16°C were transferred to 25°C during the adult life. An examination of the data in Table XVII will indicate that while at a constant temperature of 35°C the average longevity (under 0 mm. S.D.) was 2.8 days, parasites with pre-imaginal life at 25°C and and the adult life at 35°C lived on the average for 4.6 days. The increase in longevity is not well marked indicating that a high temperature of 35°C prevailing only during the imaginal life is fairly injurious to the parasite. The average longevity of parasites transferred from 25° to 16°C was 28.4 days *i.e.*, midway between the average longevities of 14.2 and 44.2 days at constant temperatures of 25°C and 16°C. However, when the adults were transferred from 16° to 25°C the longevity was markedly reduced.

(b) *Influence of humidity*

The data on the longevity of adults which passed their pre-imaginal life under saturation deficiencies of 0, 3 and 14 mm. is given in Table XVII. It will be noticed that the average as well as maximum duration of life was longest under 3 mm. S.D. For instance at 25°C, the average longevity was 14.2, 16.8 and 12,3 days under 0, 3 and 14 mm. S.D., the corresponding maxima being 31, 36, and 20 days. Furthermore, although the longevity was reduced both by the rise and fall in S.D., the effect was much more marked under dry conditions of 14 mm. S.D. than under a saturated

TABLE XVII. *The longevity (in days) of copulating pairs of* M. greeni lefroyi *(fed on honey) at different temperatures & S. D.*

Temperature °C		S. D. o mm.					S. D. 3 mm.					S. D. 14 mm.				
Pre-imaginal	Imaginal	No. of adults	Average longevity	Maximum longevity	Average longevity of sexes		No. of adults	Average longevity	Maximum longevity	Average longevity of sexes		No. of adults	Average longevity	Maximum longevity	Average longevity of sexes	
					Males	Females				Males	Females				Males	Females
16	16	14	44.2	72	33.5	55						*16	*24.9	*39	*21	*28.4
20	20	15	15	38	13.2	17.3	24	25.4	53	23.4	27.4	23	22	42	18	23.5
25	25	24	14.2	31	11.5	15.2	24	16.8	36	16.5	17.2	18	12.3	20	10.4	14.2
30	30	15	13.6	27	11	15.0	24	15.2	30	13.7	16.3	16	7	10	6	8
35	35	21	2.8	4	2.7	3	26	3	1.5	1.3	1.8					
25	35	27	4.6	16	4.1	5.1	17	6.3	18	6.1	6.6	18	12.7	20	11.8	13.6
25	16	18	28.4	58	26.4	30.4	24	47.2	86	38.8	55.6	31	41.1	79	28	53.2
16	25	19	10.6	21	8.4	12.8	14	14	23	9	15.9	16	7.3	13	7	7.6

*These observations are at 9 mm. S. D.

condition of 0 mm. S.D. The results are similar in the case of variable temperature experiments. The average longevities at various temperatures were generally highest under 3 mm. S.D., and became shorter when the S.D. deviated from 3 mm.

(*c*) *Influence of food*

The provision of food in the form of honey solution to the adults prolongs their life considerably. A comparison of the longevity figures in Table XVIII shows that average life of fed-parasites was 15-25.4 days at 20°C and 14.2-16.8 days at 25°C against 9-10.7 and 4.7-7.2 days respectively in the case of unfed ones. The difference in the maximum

TABLE XVIII. *The longevity (days) of fed and unfed adults of* M. greeni lefroyi *at some temperatures and S.D.*

Temperature °C		S. D. mm.	Longevity of adults fed on honey		Longevity of unfed adults	
Pre-imaginal	Imaginal		Average	Maximum	Average	Maximum
20	20	0	15	38	9	15
		3	25.4	53	10.7	20
25	25	0	14.2	31	4.7	9
		3	16.8	36	7.2	15
25	16	0	28.4	58	12.9	29
		3	47.2	86	21.7	49
25	35	0	4.6	16	2.1	6
		3	6.3	18	3.6	7

duration of life of fed and unfed parasites under same conditions of temperature and humidity is still greater. Thus, whereas the maximum life of fed parasites was 53 and 36 days at constant temperatures of 20° and 25°C (under 3 mm. S.D.), that of the unfed parasites was 20 and 15 days under the same conditions.

(*d*) *Influence of copulation*

The data regarding the longevity of copulating adults under different conditions have been already presented in Table XVII; those for adults not allowed to copulate are given in Table XIX. A comparison of the two tables makes it clear that the adults allowed to copulate lived invariably longer than those not allowed to do so. It will be observed that the average longevity of copulated adults was 15 and 14.2 days at 20°C and 25°C under 0 mm. S.D. and 25.4 and 16.8 days at the two

temperatures under 3 mm. S.D. against 12 and 6 days under 0 mm. S.D. and 15.2 and 10.3 days under 3 mm. S.D. at the respective temperatures in

TABLE XIX. *The longevity (in days) of uncopulated adults of* M. greeni lefroyi *fed on honey solution at some temperatures and saturation deficiencies*

Temperature °C		S. D. 0 mm.					S. D. 3 mm.				
Pre-imaginal	Imaginal	No. of adults	Average longevity	Maximum longevity	Average longevity of sexes: Males	Females	No. of adults	Average longevity	Maximum longevity	Average longevity of sexes: Males	Females
20	20	22	12	17	11	13	30	15.2	28	12.8	17.7
25	25	30	6	11	6	6	42	10.3	22	10.0	10.6
35	35	32	2.7	9	2.6	2.75	26	2.4	26	2.3	2.5
25	16	24	25.7	41	25.5	26	36	32.6	49	31.2	36.6
25	35	24	5.4	11	5.4	—	26	4.7	7	4.7	—

the case of uncopulated pairs. Likewise the average and maximum durations of life of adults under variable temperature experiments were higher in the case of copulating adults. Thus, under almost all conditions tried, the copulating adults (both sexes) lived longer than those not allowed to copulate.

VI. PRELIMINARY EXPERIMENTS ON THE FEASIBILITY OF MASS-MULTIPLICATION OF THE PARASITE

In our previous paper (*op. cit.*) we emphasized the fact that this parasite sedulously avoids ovipositing on exposed larvæ of *Earias*, restricting its oviposition to well-developed larvæ only. Therefore, for breeding the parasite, the method hitherto employed consisted of supplying the parasite with more or less full-grown larvæ inside fresh *bhindi* pods. This is however very cumbersome, particularly when it is desired to build up large material of this parasite. Some of the difficulties and methods for overcoming these are dealt with below :

(a) *Difficulties in the mass-multiplication of the parasite.*

There are several difficulties involved in the mass-rearing of the parasite. The more important of these are :

(*i*) The food of the bollworms must always enclose the larvæ, as naked larvæ are not accepted by the parasite. Fresh vegetable matter being the only suitable food of the larvæ of *Earias*, it has to be changed very frequently in the dishes, particularly at high temperatures where it rapidly decays and attracts various kinds of fungi and bacteria. This frequent changing of food just to provide the necessary cover for the larvæ which are otherwise quite suitable for oviposition for several days, involves a considerable amount of manual work.

(*ii*) *Earias* larvæ are not available in large numbers at certain times of the year and unless special cultures are artificially maintained at suitable temperatures, the experimental work is interrupted for long intervals.

(*iii*) As only well-developed *Earias* larvæ are accepted for oviposition and there is no real hibernation in this species, the suitable stage for parasitisation is available only for a short time. Furthermore as a result of this, it is also not feasible to collect large numbers of bollworms when in plenty and 'store' them under suitable conditions of temperature for period of scarcity.

(*iv*) No alternate host was yet known which could be acceptable to the parasite as readily as the *Earias* larvæ and thus act as a substitute, when the latter was scarce in nature.

Several attempts were made to overcome these difficulties and the results achieved so far are given in the following account:

(*b*) *Suitability of the prepupal stage of* Earias *spp. for parasitisation*

When *Earias* larvæ are full-grown, they often leave the fruit, find out a suitable corner in the rearing dish and start spinning cocoons. The completion of cocoon takes several days and the transformation into pupa takes yet a few more days. During this stage, called the prepupal stage, the larva requires no food and is covered with the silken cover of its cocoon. This stage lasts for about 7-10 days at 16°C and correspondingly less at higher temperatures. It was discovered during the present investigation, that the parasite readily accepted such larvæ for oviposition. The cover of the cocoon satisfied the instinct of the parasite to puncture through a layer before ovipositing and thus so many difficulties involved in the provision of fresh plant food were done away with. In practice, full-grown larvæ near spinning were liberated in the experimental dishes. Within 24 hours or so they prepared a thin covering when the parasite was introduced for oviposition. The hosts remained suitable for parasitisation for several days and it was not necessary to do anything further for at least a week or so. By this time the majority of the larvæ were parasitised and the remaining pupated; therefore, the parasite pair was removed from this dish

and introduced into another cage prepared in the same manner. Several parasites were thus reared from the prepupal stage of the host without much difficulty. The number of eggs laid by the parasite on this stage of the host was not in any way below normal. In fact the maximum number of eggs (589) laid by a single female so far, was recorded when the host was offered in the prepupal stage (Table XV).

(c) *Larvæ of the pink bollworm,* Platyedra gossypiella *as an alternate host*

It is already known that larvæ of *Platyedra gossypiella* (Saund) are sometimes parasitised by *Microbracon greeni lefroyi* (Fletcher and Misra, 1919) but the economic significance of this record had not been appreciated so far. During the year 1939, the incidence of the pink-bollworm was very high in the cotton fields of the Imperial Agricultural Research Institute, New Delhi; the spotted bollworms were on the other hand very rare. In the course of examination of damaged bolls of cotton, it was discovered that the pink-bollworms were parasitised by *Microbracon greeni lefroyi* to a fairly large extent. Full grown larvæ of this host enclosed in *bhindi* pods were offered to the parasite in the laboratory and the latter took to them very well. The larvæ were freely paralysed and eggs laid on their body as readily as on *Earias* larvæ. The parasite grubs fed very well on this host and developed into adults in the normal period.

It is well known that the pink-bollworm regularly hibernates in the larval stage (the long-cycle phase) as soon as cotton matures and dry conditions prevail. Under most of North Indian conditions the larvæ begin to enter into long cycle phase towards the end of autumn and the entire winter, spring and early summer are passed in the larval stage inside hollow seeds of cotton usually joined together and called 'double-seeds'. From October onwards these larvæ are thus available in large numbers both in the mature bolls and in double seeds of cotton available from the ginning factories throughout winter and can be easily utilised for mass-multiplication of the parasite particularly during the period when the normal host *Earias* spp. is scarce.

(d) *Storing of parasites at low temperatures*

It is often noticed that the parasite is abundant in the field during autumn, soon after the monsoon rains are over. Thereafter in autumn, it dwindles down in numbers, till it becomes very scarce during the ensuing spring. In order to be able to tide over long periods of unfavourable field conditions, experiments were conducted to explore the possibilities of storing the parasite at suitable low temperatures. After several preliminary experiments temperatures close to the threshold of development,

viz., 13°-16°C were found most suitable. Temperatures lower than this when prevailing for long periods were injurious to the species and caused high mortality, temperatures higher than this induced active metabolism, thereby reducing the pre-imaginal as well as imaginal lives.

During the autumn of 1938, parasite material was abundant in nature. Both immature and adult parasites were collected and kept at 13°-16°C. The adults were fed regularly on honey solution. From the data presented in Table XX it will be observed that the average longevity of males was 33-49 days and of females 45-73 days. The maximum durations of life

TABLE XX. *Some data on the safe storing of* M. greeni lefroyi *for a long period at low temperatures*

Incubation and larval periods at	Pupal period at °C	Duration of pupal period (days)	Imaginal life at °C	Longevity					
				Male			Female		
				Average	Maxi-mum	No. of adults	Average	Maxi-mum	No. of adults
16°C	16	20.24	16						
20°—24°C (Laboratory)	16	,,	,,	35.2	79	37	45.7	95	28
November field conditions	16	,,	,,	47.7	72	17	73.2	138	21
December field conditions	16	,,	,,	49	68	13	67	111	11
16°C	13—16*	42—48	16	33	37	4	47.5	59	4

* The pupal period was passed partly at 13°C (22.x to 20.xi) and partly at 16°C (21.xi to date of emergence).

were 79 and 111 days respectively. Some of these females kept for over 3 months, copulated and laid a small number of eggs when brought to a suitable temperature. These experiments indicate the possibilities of collecting the parasite when abundant and successfully storing it for over four months to pass over unfavourable conditions of environment.

(*e*) *Advantages of improved technique*

The results so far obtained with experiments designed to overcome the difficulties involved in the large scale rearing of the parasite may be summarised as follows :—

(*i*) The necessity of constantly supplying fresh cotton bolls to the host larvæ in order to get oviposition by the parasite which lays eggs only

on covered larvæ, has been avoided. The full-grown host larvæ after spinning the cocoon but before transforming into pupa are readily accepted by the parasite for oviposition. This discovery will help a long way to prepare and offer large amount of suitable host material for the rearing of the parasite without its vegetative cover which was hitherto considered necessary.

(*ii*) The fact that the pink-bollworms have been found to be fairly readily acceptable to the parasite for oviposition solves the problem of the scarcity of host. *Earias* larvæ are not available throughout the year particularly in the well-developed stage in which they are normally parasitised. In pink bollworm we have an alternate host which is available in large quantities during winter, which can be easily collected from September onwards and stored in a hibernating condition for several months.

(*iii*) A temperature of 13°-16°C has been found to be quite suitable for keeping the parasite material in a viable state for over three months. It would be now feasible to collect the parasite in November when it is usually common and utilise it in next spring when it becomes very scarce in nature.

VII. HOST-PARASITE INTERACTION

We have discussed the influence of various factors of environment on the fecundity and longevity of host and parasite separately. We will now consider their influence on the comparative rates of reproduction and multiplication of the two and their interactions.

(*a*) *Influence of temperature*

(*i*) *Fecundity.*—From a comparison of Tables IV and XII it will be noticed that at a temperature of 16°C, which is very close to the threshold of both the host and parasite, the fecundity of the host was immensely depressed, being only 11.5% of its average fecundity at 25°C; that of the parasite, on the other hand, was proportionately less affected, remaining about 27.5% of its fecundity at 25°C. It may thus be concluded that low temperatures affect the fecundity of the host more than that of the parasite.

The optimum range of temperature for egg-laying lies between 25° and 30°C for the host as well as the parasite; a temperature of 25°C being best for the both. Thereafter, the rise of temperature affects the fecundity of the parasite more injuriously than that of the host. With regard to the upper limit of temperature, whereas the host continued laying some eggs up to 35°C the parasite became completely sterile at this temperature. These observations go to show that high temperatures in the neighbourhood of 35°C are more injurious to the parasite than to the host, thus confirming our findings on the rate of development previously reported.

With regard to the part played by the pre-imaginal and imaginal temperatures in influencing the fecundity of the resulting adults, it will be noticed that the host adults reared from material kept at 25°C and transferred to 35°C during adult life or *vice versa* showed a marked improvement in their fecundity as compared to those individuals which were kept throughout at 35°C, *viz.*, during pre-imaginal as well as imaginal life. The parasite on the other hand showed only little improvement in fecundity when reared from material at 25°C and thereafter transferred to 35°C. This again proves that even if the pre-imaginal temperature is favourable, the parasite is disabled to lay eggs if transferred to a high temperature of 35°C during the adult period, whereas the host is not so much affected.

(*ii*) *The reproductive potential.*—The effective reproductive potentials of host and parasite are given in Tables VI & XVI respectively. At a constant temperature of 16°C, the host cannot maintain its existence while the parasite can. The host possesses maximum reproductive potential at 30°C, the parasite at 25°C. Thus low temperatures are injurious to the host, high temperatures to the parasite. At a constant temperature of 35°C both the host and parasite become extinct. Furthermore, leaving aside the extremes of temperature, *viz.*, 16° and 35°C, the reproductive potential of the parasite is almost double that of the host at all the temperatures (20° to 30°C).

(*iii*) *Longevity of adults.*—At 16°C the parasite adults had more than double the life of the host adults. Between 20° and 30°C both lived roughly for a fortnight. At 35°C the host lived for 5-11 days (Table VII), the parasite died within 2-3 days (Table XVII). Here again the more favourable influence of low temperatures and more injurious effect of high temperatures on the parasite as compared to that on host are obvious. Taking maximum duration of life at various temperatures alone it will be seen that the parasite lived comparatively a longer life than the host. The females of both the host and parasite lived longer than their males. Again, the longevity of host and parasite adults was considerably prolonged when they were reared from material at suitable high temperature (25°-35°C for the host and 25°C for the parasite) and the resulting adults transferred to 16°C the conditions prevailing from autumn to winter.

(*b*) *Influence of humidity*

(*i*) *Fecundity and reproductive potential.*—The data on the influence of relative humidity of air prevailing during the pre-imaginal stages on the fecundity of the resulting adults has been presented in Tables IV and XII. It will be noticed that the effect is not quite uniform at all the temperatures. But on the whole, at temperatures of 25°C to 30°C which is the optimum range of development for both, the fecundity of host was distinctly lowered

under a saturated atmosphere, and that of the parasite under rather dry conditions (14mm. S.D.). The reproductive potential of the host (Table IV) showed little variation under different conditions of saturation deficiencies at 25°C; but at 30°C, it distinctly rose as the conditions grew drier; that of the parasite (Table XVI) on the other hand was maximum under 3 mm. S.D. at 20°C, under 0-3 mm. S.D. at 25°C, and under 0 mm. S.D. at 30°C. Thus on the whole moist conditions are more favourable to the parasite than to the host.

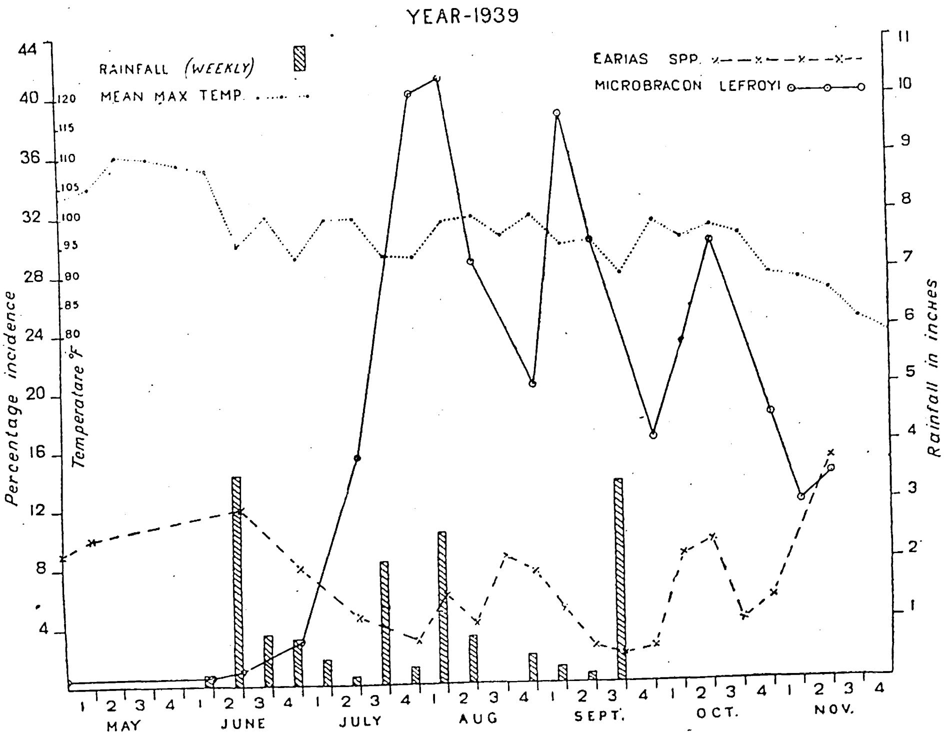
(*ii*) *Longevity of adults.*—From a reference to Tables VII and XVII it will be found that the adults of host as well as parasite emerging from material reared under 3 mm. S.D. were comparatively longer lived at various constant temperatures than those reared under 0 mm. or 14 mm. S.D. In variable temperature experiments, however, a saturated atmosphere distinctly shortened the life of host adults but not so that of the parasite adults.

VIII. COMPARATIVE INCIDENCE OF HOST AND PARASITE IN THE FIELD IN RELATION TO ENVIRONMENTAL FACTORS

In order to test the validity of the conclusions derived from laboratory experiments, weekly incidence of *Earias fabia* and *E. insulana* and their parasite *Microbracon greeni lefroyi* was determined in the cotton fields at Delhi from May to December during 1939 and 1940 and correlated with rainfall and temperature. A weekly examination of 300-500 buds and bolls collected from a number of cotton plants was carried out and the number of attacked buds and bolls was recorded. In the same manner, the number of healthy and parasitised bollworms recovered from this material as well as from shed buds and bolls was determined to find the incidence of *M. greeni lefroyi*. The data thus collected are graphically plotted along with weekly rainfall and weekly mean maximum temperatures in Fig. 1.

A study of the incidence curves of the host and parasite for the two years shows that during May and June, which were the hottest and driest months at Delhi, the incidence of bollworms remained high, while that of the parasite was extremely low. The mean maximum temperature during this period was generally above 100°F sometimes reaching as high as 110°F. This coupled with practically no rain during this period produced conditions injurious to the parasite and favourable to the host. With the first showers of rain towards the end of June and the consequent rise in relative humidity and fall in temperature, the incidence of the parasite shot up and that of the host gradually decreased. Even with about a quarter inch of rainfall in the first week of June 1940, the incidence of the host decreased from 27% to about 12% in the second week of June.

During July and August there had been good and well spread rains. On account of its rapid development under favourable conditions of mild



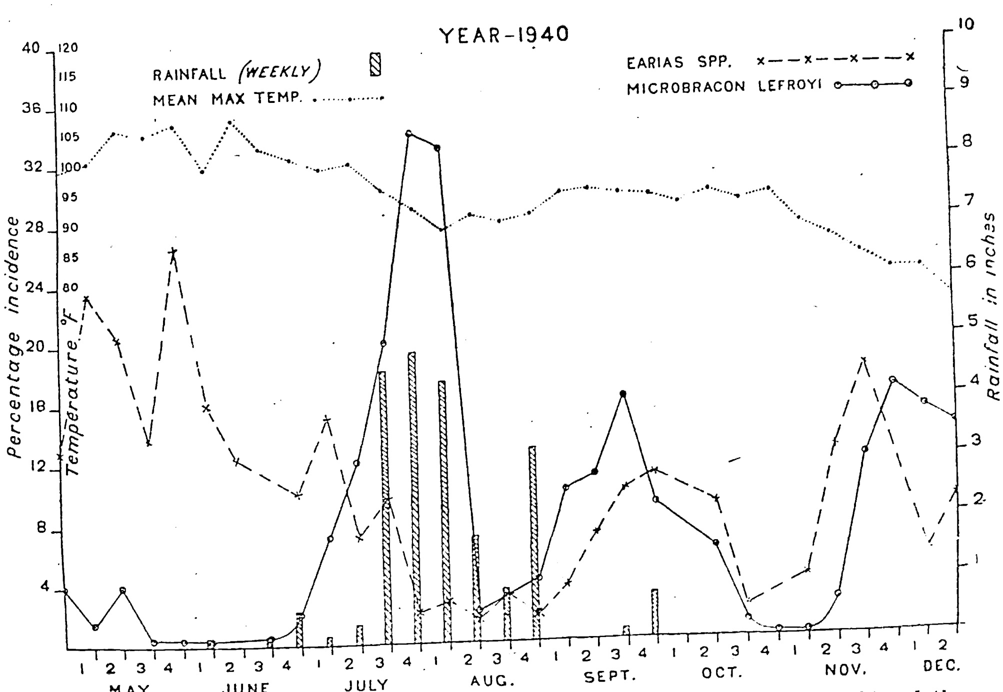


Fig. 1. Weekly incidence of *Earias* spp. and their parasite *Microbracon greeni lefroyi* in relation to temperature and rainfall in cotton fields at Delhi during 1939 and 1940

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temperature and high humidity, the parasite reached its maximum activity (36-40% parasitisation) about the end of July in both the years. Consequently the host was at its lowest (2-4% incidence) during this period. However, later in August, it will be noticed that the incidence of the parasite began to decline. This seems to be the natural outcome of the exhaustion of its own food, *viz.*, the host larvæ, brought about by high parasitisation on the one hand, and high humidity unfavourable to the development of the bollworm on the other hand. But the fall in the incidence of the parasite during the August of two years is somewhat different. In 1939 August, the rainfall was comparatively less, so that the host was not completely wiped out and food was available in fair quantity for the parasite. Thus the incidence of the parasite did not decline below 20%. In 1940 August, the rainfall was more and better spread out, thus almost completely hampering the development of the host and so annihilating it that the parasite population immensely declined for want of food.

During September the rainfall declined considerably but more so in 1940 than in 1939. Thus during 1939 September, owing to comparatively better rainfall, the incidence of host remained low; with the cessation of rains in October it increased till it reached about 16% in the middle of November. The parasite on the other hand, although immensely fluctuating from time to time, remained fairly abundant and on the whole steadily decreased as the dry season approached. In 1940, from September onwards the host incidence declined first and then rose again in November. The parasite during this period, although not as abundant as in 1939, closely followed the host and kept it well under control. During November there is usually a fresh flush of green buds on cotton crop at Delhi, which probably accounts for the tendency on the part of the host to increase at this time. It will be noticed that on the whole, the nature of incidence curves of the host and parasite is similar during 1939 and 1940. Thus, although the pest was fairly common in the early stage of the cotton crop, due to good and well spread rains, the parasite soon predominated and kept the host well under check during the most critical part of the crop's growth. Therefore, the spotted bollworms did not assume any serious status during the two years under discussion.

These observations in the field go a long way to confirm our laboratory findings that the beneficial effect of rains in controlling the spotted bollworms is due to the lowering of temperature which is beneficial to the development and multiplication of the parasite and raising the humidity which is injurious to the host.

IX. CONCLUSIONS AND SUMMARY

This is the second contribution of a series of critical ecological investigations on the cotton bollworm, *Earias fabia* and its parasite

Microbracon greeni lefroyi. In the first paper (Ahmad and Ghulamullah, 1939) we dealt with the rates of development and viability of the pre-imaginal stages of the host and parasite under different conditions of temperature and humidity ; in the present contribution data on the fecundity and longevity of adults of the two under different conditions are presented. A short account of their incidence in nature in relation to weather conditions is also appended.

At a low temperature close to the threshold, *e.g.*, 16°C, the fecundity of both the host and parasite is reduced, but it is noteworthy that the fecundity of the host is much more affected than that of the parasite. The reproductive potential of the host is barely 1.0 against about 4 for that of the parasite. Thus, whereas the parasite can easily maintain itself and multiply at a continuous temperature of 16°C, the host cannot. This confirms our previous observation that contrary to the common belief, low temperatures are more injurious to the host than to the parasite. Between 20° to 30°C, the reproductive potential of the parasite is roughly double that of the host. The host possesses maximum reproductive power at 30°C, the parasite at 25°C. With regard to upper limit, the host continues laying some eggs up to 35°C, while the parasite becomes completely sterile. Similarly if a temperature of 35°C prevails during a part of the insect's life, *viz.*, pre-imaginal or imaginal period only, the disparity in the fecundity of the host usual at a continuous temperature of 35°C is practically removed and it lays almost normal number of eggs but that of the parasite is only slightly removed. These observations again confirm the previous finding that high temperatures are more injurious to the parasite than to the host.

It has not been possible to control the humidity conditions during the adult life, but the pre-imaginal stages of the host and parasite reared under different conditions of saturation deficiencies produced significant effect on the reproductive power of the resulting adults. At the optimum range of temperature *viz.*, 25° to 30°C, the fecundity of the host is distinctly lowered if they are bred from material under saturated conditions, that of the parasite is reduced when they are reared from material under rather dry conditions (14 mm. S.D.). Thus the reproductive potential of the parasite adults is usually maximum when they are bred from material kept under more or less moist conditions of 0-3 mm. S.D. This supports the conclusion already arrived at, that moist conditions are generally more favourable to the parasite than to the host.

The longevity of parasite adults is more than double that of the host adults at a low temperature of 16°C. Between 20° and 30°C the adults of both live for about a fortnight or so. At 35°C the host adults live for over four days while the parasite dies within 2-3 days. Here again the more favourable effect of low temperatures and more injurious influence of high temperatures on the parasite, as compared to the host are obvious.

The females of both the species live longer than their respective males.

In order to test the validity of these laboratory conclusions in the field, the incidence of *Earias* spp. and *Microbracon greeni lefroyi* was determined by weekly examination of cotton buds and bolls in the cotton fields of the Imperial Agricultural Research Institute, New Delhi, during 1939 and 1940. The data thus collected for two years have been graphically plotted and correlated with temperature and rainfall. In both the years it has been noticed that with the first shower of rain, the parasitisation of the bollworms began to increase. Thereafter, as the rains were well spread throughout summer and the temperatures remained moderate, the parasite continued to be active with the result that the pest did not become serious.

These observations in the field lend considerable evidence to support the laboratory conclusions that rains in summer help in controlling the pest by lowering the temperature which is beneficial to the parasite and raising the humidity which is injurious to the host.

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STUDIES ON *SCHISTOCERCA GREGARIA* FORSK

AN ACCOUNT OF LOCUST VISITATIONS IN INDIA DURING THE LAST CYCLE (1926-31)*

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CONTENTS

I. INTRODUCTION

How often has the desert locust (*Schistocerca gregaria* Forsk.) invaded India and since when has it devastated the vegetation of this ' continent '? It is not possible to answer this question, because *Schistocerca gregaria* is certainly more ancient than man. If Egyptian history provides a clue India must have suffered from locust attack long before mankind inhabited it. It was but ' yesterday ' that reports about locust visitations began to find place in government records. On the basis of the information available, since 1843 swarms of desert locust have swept over parts of this country during the following years : 1843, 1863-66, 1869-73, 1876-80, 1889-94, 1899-1907, 1913-1917 and 1926-1931. Unfortunately these records are merely of historical importance, as they do not throw much light on any of the numerous problems involved in locust study. This is not surprising when one considers that even the records of the last visitation—1926-1931—are not complete. There are serious gaps and in many cases the information recorded is obviously incorrect. While Baluchistan, Sind, States

*For detailed information reference may be made to:—"Data on the movements and activities of swarms of the desert locust, *Schistocerca gregaria* in the Northern and Central Parts of India" Part II, compiled by the staff of the Locust Research Entomologist, Lyallpur; Government of the Publication, Calcutta, 1940.

of western India, Rajputana, the Punjab, the North-West Frontier Province, the United Provinces and certain parts of the Central Provinces and Behar and Orissa suffered the most, Central India, Bombay, Hyderabad (Deccan), Bengal and Assam were also invaded towards the end of the cycle in 1930.

Although the swarming activity diminished and gradually ceased after 1931 we are aware that individuals of the 'solitary phase' are always present in the so-called 'permanent breeding grounds', *viz.*, southern Baluchistan, some parts of Sind, Rajputana, Bahawalpur and Dera Ghazi Khan (a south-western district of the Punjab). The locust population may increase considerably, as the climatic conditions become favourable and they may assume dangerous proportions again.* We must always keep ourselves prepared for the combat. Therefore an account of the last visitation will not be without useful lessons. We need answer to wherefrom and under what circumstances locusts usually migrate; how they spread over the various parts of the country; what are the regions they can breed in; what are the limits, if any, of the actual spread of the swarms; which routes they follow to reach the various tracts; where do they become very serious; and how do they respond to the different climatic and weather conditions they meet with? A study of the records of the last locust visitations may not furnish adequate answers to all these questions, but will enable us to understand the problem in its various aspects during the cycle which has recently started. Keeping this in view the record has been thoroughly analysed and the information mapped, using the International symbols (International Locust Conference 1932).

It may, however, be made clear that it is not implied that locusts, reappearing in India, will rigidly follow the route taken by the swarms in 1926-31 and would not trespass the limits of their regional activity. Still, the data will furnish general and broad indications regarding their probable routes in the country. Thus, timely warnings could be given to the areas concerned and the arduous task of locust campaign made easier and successful.

This study was carried out under the Locust Research Scheme, financed by the Imperial Council of Agricultural Research, India. My thanks are due to the Council for their generosity. I am also thankful to Rao Bahadur Y. Ramachandra Rao, Locust Research Entomologist, Karachi and to Government Entomologist, United Provinces, for lending us certain records. I acknowledge the help given to me by my Assistants, Mr. C. B. Mathur and Mr. Abdul Haq, in compiling the data presented in this report.

*This has actually happened.

II. Sources of Error

During a locust invasion all those entrusted with the control and destruction of the pest are as a rule so overworked, that they find very little time to record and study even important facts. Errors arise generally from the following sources :

(1) *Absence of reports.*—Lack of reports of locust visitations is by far the greatest stumbling block in preparing a connected account of locust flight, breeding, etc. It will not be an exaggeration to say that the reports received represent but a small fraction of the stupendous locust activity. Therefore, in order to obtain a more or less connected view of things, one has to fill in blanks. For instance, a swarm was reported to have visited Chamba (Punjab) on 7th and 8th October, 1931, but about the same time no swarm was reported from adjoining districts. Chamba being surrounded by high hills, this swarm must have come from outside. In the previous week (29th September, 1931) a swarm was reported from Gurdaspur (Punjab) and if it was the same swarm which later visited Chamba, it is not known as to what places the swarm visited between 29th September and 7th October. Nor is the pervious history of the swarms which visited Gurdaspur certain. Again a swarm that passed over Sheikhupura on 16th July, 1931 and Lyallpur and Lahore on the 17th is not linked with any other swarm, no locust visitation having been reported from any of the districts adjoining the above-mentioned three districts.

For the United Provinces the record of 1927 is very incomplete. Locust swarms were reported to have reached Nainital on 25th June, 1927. After a few days (28th June) swarms appeared in Muzaffarpur (Bihar). No reports of locust visitations from the intervening long stretch of land are on record for the same period. This swarming could not have been local and, therefore, the locusts must have transversed, though unrecorded, the intervening region.

(2) *Incomplete reports.*—Incompleteness of reports is another source of error. In most cases where hoppers were reported their stages were only rarely mentioned. In such cases it is difficult to say from which group of eggs, laid earlier in that locality, did the hoppers hatch out or which swarm of fliers, reported later, did they give rise to.

Similarly, the colour of fliers was seldom reported, which is so important for determining the stage of maturity.

(3) *Incorrect reports.*—Most of the reports were sent in by *patwaris*, who do not often realise the importance of the problem. Quite often reports, evidently incorrect, were sent in and it is not always possible to determine the truth, the event having passed off without leaving a trace. Not infrequently ordinary grasshoppers, occurring in large numbers, have been

confused with the desert locust. Dragon-flies and may-flies and even swarms of small birds have been mistaken for locust swarms.

The direction of flight of swarms is very frequently misjudged, and invariably either the direction of arrival or the direction of departure only is given. Oviposition reports are often unreliable. Sometimes the mere settling down of locusts has been considered enough to justify a report of oviposition. It is on account of such mistakes that we have records of oviposition, while actually no oviposition occurred.

Sometimes enthusiastic workers on control duty, with a view to take credit for good work, report complete destruction, while it is far from it. Thus a large number of surviving individuals remain unreported.

III. Locust situation prior to 1926

In 1922, swarms of the desert locust were reported from the Dera Ghazi Khan district (Punjab) along the west bank of the Indus. (Afzal Husain, 1929, 1931) In the summer of 1923, locust swarms were reported to have visited Ormara (Rao, 1933). During April, May and November, 1924 swarms of fliers and in May swarms of hoppers appeared in Kalat State. Again in Kalat, as also in Sibi, swarms of fliers were noticed in June 1925. During the same year, swarms were reported from Dera Ghazi Khan district also. This important, though admittedly meagre information, clearly shows that for several years prior to 1926, locusts were actively multiplying in some parts of their permanent or semi-permanent breeding grounds in India and outside and were migrating out from breeding areas.

IV. Locust situation in 1926 (Plate II)

During 1926, swarms of the desert locust reached as far as Mianwali, Jhang, Lyallpur and Montgomery in the Punjab and as far south as Kathiawar. The oviposition area was more or less restricted to the permanent breeding grounds.

During June of the same year swarms were present in Baluchistan. Swarms of fliers and hoppers were reported from Kachhi and Kalat in the last week of June. Another movement reported was a swarm of fliers in Kulanch (Mekran, Baluchistan) on 26th June.

Sibi (north-eastern Baluchistan) and Kalat received swarms in July. Lasbela (south-eastern Baluchistan) was the centre of locust-activity from August to December and breeding went on during September, October and November. The first oviposition reported is dated the 27th September and the last recorded date of the presence of hoppers is 4th November. Swarms were also observed in Mekran during October, November and December, in Sibi and Loralai (north-eastern Baluchistan) during Novem-

ber and December and in Chagai (north Baluchistan) during December. During this period locust breeding was not recorded. Regarding the source of Loralai-swarms, the Baluchistan Agricultural Diaries dated December 1926, observe: "The swarms visiting Loralai appear to have their origin in the neighbourhood of Dera Ghazi Khan (Punjab)". This observation finds support in the fact that incipient swarming occurred in the Indus valley in Dera Ghazi Khan District in 1925 (Afzal Husain, 1929-1931). It may be mentioned that locusts of the solitary phase have been found breeding in this region from 1931 onwards, giving support to the view that Dera Ghazi Khan is a permanent breeding ground and thus a source of swarming. During December 1926, swarms of fliers visited Loralai (Baluchistan), as well as some south-western districts of the Punjab. These swarms undoubtedly were of Sind-Baluchistan origin.

Winged locusts were present in the Karachi district from September to December, in the Hyderabad district (Sind) from October to December and in the Nawabshah during November 1926. Hoppers were actually noticed near the river Hub (Karachi) in November 1926, showing that adults had laid eggs in this locality sometime in September. In Tharparkar district (Sind) hoppers hatched out by the end of August, from the eggs that must have been laid in the beginning of the month. Further ovipositions were recorded about the end of August and during September and hoppers appeared in very large numbers in October. Pink adults were observed flying from east to west during October and November.

In August 1926, locusts swarmed from the west into the Mallani area (Jodhpur state) adjoining the Tharparkar district (Sind) and extensive breeding took place in August and September.

The first swarm of this locust-cycle in the States of western India was reported on 1st of November, having entered Palanpur from the South. This was followed by another swarm of pink locusts on the 30th November in Halar (Kathiawar). During December a number of swarms, moving in different directions, were observed in Palanpur, Jhalawar, Halar and Sorath. One of these swarms that visited Halar on 4th December consisted of pink adults.

The first locust swarm invaded the Punjab on 16th of December 1926, entering the Rajanpur tehsil (Dera Ghazi Khan district), in the extreme south-western corner, from the south-western direction. Swarms visited the four tehsils of the district on different dates :—

Rajanpur (south-western tehsil)	on 16th and 17th December.
Jampur (north of Rajanpur)	on 18th and 19th December.
Dera Ghazi Khan (north of Jampur)	on 19th December.
Sangarh (northern tehsil)	on 22, 23 and 24th December.

Thus, the swarms travelled from south to north. A portion of these swarms visited some of the tehsils of Muzaffargarh district, and locust swarms were reported on the 20th and 22nd December from Alipur, on 24th from Kot Adu and on 24th and 25th from Muzaffargarh. The direction of flight of these swarms was from south-west to north-east.

Multan was first visited on 21st of December from north-east, again on the 23rd from west and then on 24th December from east. The Mianwali district (north of Dera Ghazi Khan) was invaded from the south from 22nd to 28th December. A swarm visited Okara (Montgomery district) on the 28th December. The direction from which the swarm entered the Montgomery district is not known; it is very likely that it came from the Multan district where locusts were active about this time.

V. LOCUST SITUATION IN 1927 (Plate III)

January.—The end of 1926 witnessed general activity

During January 1927, over-wintering swarms were recorded from Baluchistan, Sind, States of Western India, Jodhpur (Rajputana) and the western Punjab. In Baluchistan they were reported from Mekran, Chagai, Quetta, Sibi, Kharan, Jhalawar and Lasbela. In Chagai the swarms evidently came from west (most probably from the adjoining tracts of Irān) and passed on towards east on the 4th January. It is very probable that the swarms appearing in Quetta had also a similar origin. The swarms which visited Lasbela on 9th and 10th January came from the west and most probably gathered from Mekran. They passed on to Karachi. During the last week of January, a swarm was recorded in Sibi on 27th and another from Mekran on 31st January. Thus it seems that the swarms having emigrated, there was little locust activity in Baluchistan.

In Sind, fliers were recorded damaging the *rabi* crops in Karachi, Hyderabad, Tharparkar and Nawabshah districts. In the States of Western India and Jodhpur they remained throughout the month.

In the western half of the Punjab, swarms were actively flying about throughout January. After effecting an entry through Dera Ghazi Khan in December, 1926, the fliers made their way towards north and east into the interior of the province and spread in a fan-like fashion over the Punjab. Broadly speaking, the swarms migrated in the north-eastern direction up to the Indus and its tributaries. By the end of the month they had reached as far north-east as Jhelum, Gujrat and Sialkot, and as far east as Gurdaspur, Sheikhupura and Lahore. Thus during January 1927, no locusts had been reported from Attock and Rawalpindi on the extreme north and from Amritsar, Jullundur, Hoshiarpur, etc., on the east.

It is interesting to note that during the month and a half (*i.e.*, from the middle of December to end of January) that the locust fliers had been

invading the province, the south-eastern Punjab remained free, except the Gurgaon district, which was visited during the last week of January. This visit must be considered as an independent invasion from the adjoining tract of Rajputana. Unfortunately no information is available from this locality. Another interesting feature of the locust movements was that the Dera Ghazi Khan and Muzaffargarh districts remained practically free of locust during January; only one swarm being reported from the latter district, on 17th January, which probably came back from Multan, where, for the first time in the month a swarm was reported to be flying from east to north on the 16th. Although no fliers were seen in Muzaffargarh during the second fortnight of January, they were present all this time throughout the Multan district. Thus locust migration from Baluchistan and Sind into the south-west Punjab, which started in December ceased by the end of January. There was no breeding during the month of January.

There was no report of the presence of locust in the United Provinces.

February.—On the 5th February a swarm flying from west to east was observed over Chagai and several yellow as well as pink swarms also moving in that direction were observed in Kalat. In Loralai, Sibi and Jhalawar (Baluchistan) swarms were present practically throughout the month, but there was no breeding.

In Sind the fliers were recorded from Karachi and upper Sind-frontier on the 1st February and were also present in Hyderabad and Nawabshah.

In the Punjab, a fresh swarm entered D. G. Khan* on 1st of February from upper Sind-frontier area. It was probably this swarm that visited Muzaffargarh district from south-west on the 3rd of the month. The swarm that visited D. G. Khan on the 25th of February appears to have come from Loralai (Baluchistan). The intensity of locust infestation in February, 1927 was about the same as during the previous month. The region of activity had, however, changed. The swarms cleared out of Multan, Mianwali, Gurdaspur and Sheikhupura districts, and invaded Rawalpindi and Attock and remained there for a fairly long period. In the north the fliers spread out from Rawalpindi to Hazara in the North-West Frontier Province. The desert locust was active in eastern and south-eastern Punjab also. Swarms were recorded on 21st in Karnal and from 23rd-28th in Ambala. At Ambala damage was done and probably eggs were laid at the end of the month, as large numbers of hoppers hatched out about the 21st of March. No swarms had been reported from other districts but it appears that the above-mentioned swarms that were reported from Karnal and Ambala came through Gurgaon and Rohtak, but remained unrecorded.

*D. G. Khan—Dera Ghazi Khan.

From the States of Western India a swarm was reported from Jhalawar on the 15th of February.

During this month eggs were laid only in Kalat probably Mekran, Chagai and Kachi tracts of Baluchistan, although swarms were present in Sind, States of Western India, Punjab and N. W. F. Province.* The only exception is Ambala district, where, as stated above, fairly heavy oviposition must have occurred. The first record of oviposition is dated 21st of February in Kalat. In Chagai and Kachi oviposition was recorded on 23rd and 28th February respectively. Eggs which were laid in Ambala towards the end of February hatched about the 21st of March.

March.—The next three months, March, April and May, witnessed great locust activity and we find reports of damage from widely distributed areas. Fliers were present over large areas during the month of May.

Although oviposition began about the end of February (Baluchistan and Ambala in the Punjab), the majority of the over-wintered locusts attained sexual maturity in March.

During March reports of heavy damage were received practically from all over Baluchistan. A swarm was reported from Nawabshah (Sind) on the 5th and another swarm from Halar (Western India States) on the 7th.

In the Punjab, the fliers were reported from Kangra on the 18th March. The central Punjab was practically free of locust which concentrated in the north-western Districts and along the Indus.

The only report of locust infestation from the United Provinces was from Dehra Dun, where two swarms appeared east to west on the 2nd and 7th of March. Presumably these swarms entered the southern part of Dehra Dun district from the Ambala district (where they were active in February) and then changed east to west within the Dehra Dun district.

Oviposition during the month of March was recorded from Mekran on 13th, 17th and 18th, in Kachi on the 14th and in Chagai on 15th, 18th, 25th and 26th, in Quetta on 15th, 29th, 30th and 31st and also in Sibi (date unrecorded).

Reports were received from Rawalpindi of ovipositions on 3rd, 14th and 28th, from Attock district on 10th, 12th and 18th; from Jhelum district on 10th; from Ludhiana, on 12th and from Mianwali on 28th. Records of hatching during the next month (April) clearly show that eggs must have also been laid in Gurgaon, Montgomery, Lahore, Multan and Gujerat about the end of the third week of March.

The first report of hopper emergence was dated the 18th March from Mekran (Baluchistan) where further hatchings were recorded on 20th, 27th and 31st. Hoppers were recorded on 21st and 31st instants in Kachi,

*N. W. F. Province—North West Forntier Province.

and on 30th in Chagai and Sibi. The first hatching in the Punjab was recorded from Ambala on the 21st and on 28th March hoppers emerged in Mianwali, Rawalpindi and Ambala.

April.—Swarms were actively flying about during April, 1927 all over Baluchistan except Jhalawar, Zhob being particularly badly infested. Generally the direction of the swarms was from south to north. The hoppers that hatched out early in March must have acquired wings in April and most of the swarms appearing in Baluchistan during this month probably consisted both of the overwintered-brood as well as those of the spring brood individuals. In the Punjab while hoppers were present in comparative abundance in most of the districts, only a few districts (Mianwali, Attock, Jhelum, Ferozepore, Kangra and Simla) were infested by the adults which evidently consisted almost exclusively of the overwintered individuals. It seems, however, that these adults were dying out at this time. In the beginning of the month, Simla (2nd April) and Ferozepore (1st, 5th, 8th and 10th April) were visited for the first time. While there was no oviposition in Simla, breeding took place in the Ferozepore district. No hoppers were reported from Sind and Rajputana although a swarm was noticed on the 7th instant in Jhalawar (Western India States).

Eggs were recorded in Baluchistan, in Chagai (2nd and 14th April), Quetta and Loralai. In the Punjab oviposition was observed in Mianwali (4th and 11th April) and, judging from reports of hatching, eggs must also have been laid in Rawalpindi, Attock, Ferozepore and Ambala. In the N. W. F. P. eggs were deposited in Hazara.

There were reports of emergence and presence of hoppers in Baluchistan from Mekran (2nd, 12th, 15th and 29th April) and Sibi (30th April). In the Punjab oviposition was recorded from Multan, Montgomery, Gujrat, Lahore, Gurgaon, Attock, (week ending 11th April), Rawalpindi (11th, 18th, 28th April), Jhelum (10th April), Ludhiana (5th, 11th April), Ferozepore (28th, 29th April), and Ambala (6th, 11th, 25th April). Hoppers were observed in Gurgaon during the week ending 11th April. Gurgaon or the adjoining regions in the Punjab had no swarms in the previous months, therefore, the swarms that oviposited in Gurgaon must have come from Rajputana about which our locust records were meagre. Hatching occurring on the 15th instant in an isolated tract, Dehra Dun, in the U. P.* is not without interest.

May.—During this month swarms were numerous all over Baluchistan, particularly Sibi. In Lasbela state swarms continually moved in the north-eastern direction towards Larkana (Sind), from where they later on proceeded to upper Sind frontier and probably flew towards Dera Ghazi

*U. P.—United Provinces of Agra and Oudh.

Khan (Punjab) also. Swarms flying from north to south towards Bahawalpur State were observed in Kabirwala tehsil (Multan district) and Rajanpur tehsil of D. G. Khan district on 29th and 31st respectively. A swarm flying in the reverse direction was observed in Multan on the 30th. During the month swarms of fliers were also recorded from Gujrat, Shahpur, Mianwali, Sheikhupura, Kangra, Simla, Ambala, Karnal, Hoshiarpur and Hissar districts. Hoshiarpur and Hissar were visited on 6th and 30th respectively, these forming the first infestation of these places of the 1926-31 locust visitations. Their presence in Dehra Dun (U. P.) and Hazara (N. W. F. P.) is also authenticated.

The individuals of the spring brood started becoming adult about the middle of May in Ambala (Punjab) and this continued in other parts of the Punjab and Baluchistan.

As compared to the previous month, oviposition was poor during May. Egg-laying was reported from Quetta, Zhob, Kalat and Sibi tracts in Baluchistan. Hopper ravages on crops were reported from Mekran (11th and 17th May) and Kachi (7th May) in Baluchistan and from Mianwali (9th, 16th and 23rd May), Attock, Rawalpindi (2nd, 9th, 16th, 23rd and 30th May), Ferozepore and Ambala (5th-9th May) in the Punjab.

June.—The locust activity was on the decline. Hoppers were recorded from Kalat (7th and 10th June), and Zhob and Sibi (20th June) in Baluchistan, Mianwali (6th June) in the Punjab, Hazara in the N. W. F. P. and Dehra Dun (1st June) in the U. P. Evidently these hoppers had emerged from the eggs that were deposited in May.

The only report of oviposition for this month is from Dehra Dun (U. P.) on 8th June. This appears very doubtful and it was not followed by hatching.

Swarms of fliers (evidently of the spring brood) were present practically all over the Baluchistan, Sind and the Punjab. In the U. P. they spread from Dehra Dun to Garhwal, Almora, Bijnore and Naini Tal districts.

The record of a swarm of fliers from Muzaffarpur (Bihar) between 28th and 30th June is very striking because of the fact that there is a long stretch of land to the west of Muzaffarpur through which the swarms had passed unrecorded. This is a glaring instance of the incompleteness of our data. In Loralai (Baluchistan) a pink swarm was observed on 11th, evidently belonging to the spring brood.

July.—By the end of June the overwintered brood had almost completely died out. Thus, the locust activity witnessed in the later half of the year concerned the adults of the spring brood and their progeny. During the first week of July no eggs or hoppers were reported from anywhere in India and the number and intensity of swarms of fliers also went

down considerably. From Baluchistan three swarms were reported in the first week of the month, one on the 8th at Kalat and two at Loralai on 1st and 8th. Larkana, Nawabshah and Sukkur (Sind) were also visited. In the Punjab, locusts were concentrating in the drier parts *i.e.*, along the border districts, Multan, Montgomery, Ferozepore and Hissar, and occassional swarms were reported from Mianwali, Shahpur, Jhang and Ambala.

In the U. P., swarms were reported from Dehra Dun, Almora, Bijnore, Nainital, Garhwal and Cawnpore districts. The Cawnpore swarm does not appear to be connected with those of Dehra Dun and other districts of the north-western districts of the U. P. mentioned above, but possibly had independent origin from Rajputana or Gwalior. Locust fliers were also swarming in Bhagalpur district of Behar and possibly belonged to the same swarm that was observed in June in Muzaffarpur. It is difficult to guess the origin of the swarm recorded from Palamau on the 5th July, 1927.

During the week ending 16th July, locust swarms were observed in Loralai and Zhob in Baluchistan; in Larkana, Sukkur, Nawabshah, Hyderabad and Tharparkar in Sind; in Sheikhupura, Multan, Montgomery, Hissar and Rohtak in the Punjab, and in Dehra Dun, Garhwal and Almora in the United Provinces. Oviposition occurred in the Hissar district (Punjab) on the 16th July and in Karachi (Sind), where hoppers were reported later on. During the week ending 24th, and on 25th July ovipositions were reported from Hissar and Rohtak districts of the Punjab respectively.

In Baluchistan the only swarm of fliers reported was from Loralai, flying from north-west to south-east. In the Punjab by the end of the week locust fliers swarmed in submontane districts *viz.*, Gurdaspur, Hoshiarpur, Ambala and Simla. They were, also present in Attock, Jhang, Multan, Montgomery, Ferozepore, Rohtak and Gurgaon. In the last mentioned place oviposition occurred on 29th July.

In the United Provinces swarms were reported from Dehra Dun, Garhwal and Almora districts and in Behar from Shahabad.

July 1927 stands out prominently for the very much reduced locust activity in the western parts of India and their concentration in the south-eastern Punjab.

August.—Locust situation during August was rather interesting. Breeding started on a large scale in the Punjab, mainly in its south-eastern districts, and in Karachi (Sind). Rohtak, Gurgaon, Hissar, Ferozepore, Ludhiana, Jullundur and Montgomery districts of the Punjab were heavily infested with eggs and hoppers. The first report of hatching in the Punjab

was received on 3rd August from Hissar, where very extensive breeding took place all over the district. Swarms of fliers were also present during the month in several districts of the Punjab—Lahore, Amritsar, Sheikhupura, Gujranwala, Mianwali, Multan and D. G. Khan, but from none of these districts was breeding reported.

In Baluchistan, small swarms were seen flying about and doing damage to crops in Lasbela, Kalat, Jhalawar, Sarawan and Kachi districts.

In the United Provinces fliers were recorded only from the Almora district.

September.—During September 1927, locust activity in India was at a very low ebb and swarms were reported only from Mekran, Lasbela (Baluchistan), Karachi (Sind), Hissar, Gurgaon and Ludhiana (Punjab). In Hissar, eggs and hoppers were recorded on 5th and 12th.

October.—In the following three months—October, November and December—the locust was not reported to breed in any part of India. Stray swarms were frequently reported from the Punjab.

In October, in the Punjab, locust fliers were active only in Hissar and Montgomery districts and a swarm was recorded flying towards Bahawalpur from Multan (Punjab) on 31st October. At the end of October, the general direction of flight of swarms in Montgomery district was from east to west. Baluchistan and Sind, particularly the latter, were heavily infested and severe damage to crops was reported. The general direction of flight of swarms in Sind and Baluchistan also was from east to west. This may account for the great concentration of locusts in Lasbela and Mekran (Baluchistan) during October.

November.—In November locust activity markedly decreased and only stray swarms were seen in Montgomery, Multan (7th), Lyallpur (7th), Shahpur (28th), Hissar (28th) and Gurgaon (28th) in the Punjab and Sukkur (5th, 12th) in Sind, and Loralai, Kachi and Jhalawar (15th) in Baluchistan. They were, however, present in good numbers in Tharparkar, Hyderabad and Karachi in Sind, and Lasbela and Mekran in Baluchistan.

December.—In December the locust completely disappeared from the Punjab.

There were swarms in Hyderabad and Karachi (Sind) and Mekran and Zhob (Baluchistan). In the Western India States, a swarm flying from south to north was observed on 27th in Sorath—a coastal tract in the southern extremity.

The presence of swarms in Dehra Dun (2nd-7th) in the United Provinces is a very peculiar fact. It is probable that these were stray remnants of the swarms visiting this region in the earlier parts of the year.

It would appear that while most of the swarms which infested the Punjab during summer died out in October, November and December, at least some did migrate to the drier tracts of Bahawalpur and Rajputana. Active control measures adopted were responsible for great deal of destruction of eggs, hoppers and fliers.

VI. Locust situation in 1928 (Plate IV)

January-March.—It is noteworthy that there were no reports from the Punjab of any locust swarms during January, February and March, 1928 (see below).

As compared with the previous year, locust-breeding started earlier in 1928. In Kalat (most probably its coastal region of Mekran), oviposition started in the first week of January and hatching commenced on 9th February. Hoppers were also recorded in Karachi (Sind) in the first week of January.

During March swarms were reported from Kalat and Chagai (Baluchistan) where they oviposited and from Sibi (Baluchistan) and Koilwar (Western Indian States).

April.—Locusts exhibited increased activity during April and spread out into Sibi, Loralai and Zhob in Baluchistan and in D. G. Khan, Mianwali, Montgomery, Shahpur and Attock districts of the Punjab. More swarms from Baluchistan entered the Punjab through Dera Ghazi Khan during the last week of April. A swarm from Sibi (Baluchistan) entered the southern most tehsils of D. G. Khan on 22nd, and spread further north reaching Bhakkar (Mianwali) and Talagang (Attock) on 24th. At the latter locality they oviposited on the very day of arrival. On 28th they were again recorded in Mianwali and on 30th in the Shahpur district. The swarm that visited Montgomery on 29th, came from the adjoining tracts of Bahawalpur State.

Ovipositions were recorded in Chagai and Sibi (14th, 30th April) in Baluchistan and Attock (24th April) in the Punjab. The reports of hatchings in early May indicate, that eggs must have been laid in Shahpur, Jhelum, and Gujrat (Punjab) and in Loralai and Quetta (Baluchistan) during the first or second week of April. It seems probable, therefore, that many locusts in the hopper or flier stages overwintered unobserved in these districts and deposited eggs in early April.

Hoppers were recorded in Mekran and Chagai (Baluchistan) throughout the month and on 14th in Sibi.

May.—Locust swarms were actively flying about in Baluchistan, Sind and the Punjab during May. The interesting feature of their movement in the Punjab was that during the first ten days of the month, swarms were common in the northern half of the province and their direction of

flight was north to south generally and during the next twenty days they were present in the southern half of the province only. This emigration from the northern half of the Punjab seems to be on account of the windstorms that blew from north to south in the beginning of May. At the end of the month, Karnal, Rohtak and Gurgaon districts of the Punjab and Dehra Dun and Garhwal districts of the United Provinces were also invaded.

Eggs were recorded in Mekran (7th, 10th May), Loralai and Zhob in Baluchistan and Attock, Muzaffargarh, Multan (18th May), and Montgomery (14th May) in the Punjab.

The emergence and presence of hoppers was reported from Mekran, Quetta, Zhob and Loralai (Baluchistan) and Attock, Shahpur, Jhelum, Gujerat and Muzaffargarh (Punjab.)

June.—During June swarms were recorded from all over Baluchistan and Sind. Breeding continued in Baluchistan only and eggs were laid in Chagai and Zhob (10th, 15th June) and hoppers were observed in Mekran (2nd, 8th, 17th and 30th June), Quetta (15th June), Zhob (10th 15th June), Loralai (28th June) and Sibi (30th June). Most probably this oviposition was by the fliers developing from the spring brood.

As in May, in the Punjab there was concentration followed by migration from one part of the province to the other. In the first fortnight of June concentration of swarms was observed in south western districts. They migrated to the south-eastern Punjab in the second fortnight of June.

In U. P. swarms were recorded on the 1st and 2nd June in Garhwal and Almora districts respectively.

July.—During July, swarms were recorded in Mekran, Lasbela, Loralai and Sibi (Baluchistan), Tharparkar (Sind), eastern two-thirds of the Punjab and Dehra Dun (U. P.) ; eggs were deposited in Hissar and Jullundur districts of the Punjab on 11th and 15th and hoppers were reported from Sibi during the second fortnight of the month.

August.—During the next five months of the year locust-activity was at its ebb, only a few stray swarms having been observed in the country. Thus, while visitations were recorded in Zhob, Sibi (Baluchistan), Hissar, Gurgaon, Rohtak, Karnal (Punjab), and Jaipur (Rajputana) in the first fortnight of August, during the second fortnight locust was reported from Sibi (Baluchistan) alone.

September.—In September no swarms were reported from Baluchistan, there were a few reports from Sukkur and Hyderabad (Sind) and only one (30th) from the Punjab (Montgomery). The Montgomery swarms probably came from the adjoining desert tracts of Bahawalpur.

October.—Reports of one swarm flying from north to south in

Kharan (Baluchistan) on 24th, a few swarms in Karachi and Nawabshah (Sind) and a swarm flying from south-west to north-east in Lyallpur (Punjab) complete the record of locust activity for October.

November.—During November while only one swarm was recorded on the 6th in Sibi (Baluchistan), locusts were present in the Punjab in comparatively larger numbers, Montgomery, Lahore, Lyallpur and Mianwali districts being more seriously infested. As in September this time also swarms were seen to have entered the Punjab from Bahawalpur side.

December.—During December the only report of flier swarms is from Attock (Punjab) from 4th to 7th instant.

VII. Locust situation in 1929 (Plate V)

January-March.—During January, February and March, locust population was again very thin in India. A swarm in Kalat on 2nd, another in D. G. Khan (Punjab) on the 5th and a few in Shahpur on 16th, 28th and 31st complete the record of locust-activity for January. In February only one swarm was recorded from Sibi (Baluchistan) on the 10th. During March a few swarms were noticed in Kalat and only one was seen in Zhob on 25th. Emergence of hoppers in April reported from Quetta, Loralai and Kalat (probably Mekran region) indicate egg-laying in these districts during March.

April.—During April oviposition was reported from Kalat, Zhob, Quetta and Loralai and hoppers were observed in Mekran (11, 15, 19, 20, 29, 30 April) and Zhob (28-30 April). On 7th April several swarms entered D. G. Khan district of the Punjab from the west, flew towards the east, and reached Multan district the same day. They laid eggs in Khanewal tehsil (Multan) on 8th instant and by the 12th had invaded the adjoining districts of Montgomery, Jhang, Mianwali, Lyallpur and Shahpur. Towards the close of the month whole of the Punjab, and Dehra Dun and Garhwal districts of U. P. were infested. A report of egg-laying was received from Jhang on 27th April. The emergence of hoppers on the 18th April in Shahpur indicates that oviposition had occurred there about the end of March.

May.—Swarms of fliers were recorded throughout the month from Kalat, Sibi, Quetta, Loralai and Zhob in Baluchistan, Montgomery, Lyallpur, Multan, Jhang, Mianwali, Shahpur, Rawalpindi, Jhelum, Gujerat, Sialkot, Gujranwala, Sheikhupura, Gurdaspur, Kangra, Hoshiarpur, Simla, Jullundur, Amritsar, Lahore, Hissar and Karnal in the Punjab, Hazara in the North-West Frontier Province and Garhwal and Dehra Dun in the United Provinces.

Eggs were laid in Kalat (1-6, 15-31) , Quetta (1, 10, 15), Loralai (1st and 2nd week-ends, and 26), Zhob (10, 18), Sibi (about 15th and on 30th) and Chagai (end of the month) in Baluchistan. The only report of oviposition in the Punjab was from Simla (9) and is *very* doubtful, as it was not followed by any report of hatching.

Hoppers were reported from Kalat, Quetta, Loralai, Zhob and Sibi in Baluchistan and Attock (20) in the Punjab.

June.—Eggs, hoppers and adult locusts were present throughout June in Baluchistan and a few swarms were noticed in Sind (Nawabshah district) for the first time in the year. In the Punjab, however, the locust population had thinned down and only a few swarms were noticed in Karnal, Amritsar, Montgomery, Dera Ghazi Khan (north-east to south-west) Lyallpur, Montgomery, Jhang, Sheikhupura, Gujerat and Attock during the first 10 days of the month. Hatching was noticed in Attock district on 7th June and hoppers were reported throughout the month. No locusts were reported from the U. P. during June.

July.—During July locust swarms were recorded from practically all over the Baluchistan and Sind. In the Punjab they were concentrated in the southern half of the Province. The presence of hoppers and freshly emerged adults in Bharatpur (Rajputana) in the first fortnight of July indicates the probabilities of certain swarms having migrated into this region from the adjoining districts of Gurgaon (Punjab) in winter 1928. From Bharatpur the locust swarms passed on to Aligarh (U. P.) on the 5th and 8th and reached Barabanki (U. P.) on 20th. Hoppers were reported from Zhob (1-15th) and Quetta (30th), in Baluchistan and from Multan (17th), in the Punjab.

August.—During the next three months *viz.*, August, September and October (more particularly August and September) numerous reports of locust-breeding were received from all over Baluchistan, the Punjab and western half of the United Provinces. During August locusts were present in Baluchistan, Sind, Rajputana, N. W. F. P., the Punjab and the United Provinces.

In Baluchistan eggs were deposited in Lasbela (3, 4, 5th) and Loralai (4, 6, 26th) and hoppers were reported from there in the last week of the month.

In the N. W. F. P. a few swarms were seen in the Dera Ismail Khan district in the first week of the month. From a report of hatching on 4th September it can be inferred that swarms of locust must have laid eggs in this district during the third week of August.

In the southern half of the Punjab locust activity was greater than in the northern half, where eggs were laid only in the Rawalpindi and Kangra districts. The emergence of hoppers began on 13th August in

Hoshiarpur district. By the end of the month hoppers were present in Hoshiarpur, Ludhiana, Ferozepore, Hissar, Gurgaon, Ambala, Attock and Mianwali, and swarms concentrated into Montgomery and Multan districts. Flights travelled north-east to south-west towards Bahawalpur.

Regarding the United Provinces, oviposition first occurred in Muttra, Budaun and Etah and lasted over the first week of August. Later on swarms invaded Moradabad, Lucknow, Barabanki, Jalaun, Muzaffarnagar, Dehra Dun, Mainpuri, Aligarh, Meerut and Garhwal and oviposited in the districts given above. Eggs laid in Etah during the third week of July hatched out on 7th August. During the last week of the month hoppers were also present in Muttra, Aligarh and Meerut.

Swarms and ovipositions were recorded from Jodhpur (Rajputana) on 15th August and hoppers were reported from Bharatpur during the second week of the month. It appears that in Ajmere-Marwara also swarms were present from 13th to 19th August. In Alwar, eggs were recorded on 21st.

September.—During September there were many reports of oviposition as well as hatching and swarms infested a much larger area than that during the previous months. In addition to Baluchistan, Sind and the Punjab, swarms visited the N. W. F. Province, Rajputana, Western India States and many districts of U. P. lying west of Lucknow.

During the month oviposition occurred in Kalat, Lasbela, Sibi (Baluchistan) ; Tharparkar, Hyderabad (Sind) ; D. I. Khan (N. W. F. P.) ; Jhang, Lyallpur, Sheikhupura, Gujranwala, Gujrat, Sialkot, Ferozepore, Hissar (Punjab) ; Dehra Dun, Unao, Cawnpore and Bulandshahr (U. P.), and hoppers were noticed in Kalat, Lasbela, Sibi, Loralai (Baluchistan) ; Tharparkar, Hyderabad (Sind) ; D. I. Khan (N. W. F. P.) ; Multan, Attock, Rawalpindi, Gujrat, Gujranwala, Sialkot, Gurdaspur, Sheikhupura, Hoshiarpur, Ludhiana, Ferozepore, Hissar, Gurgaon, Rohtak, Karnal and Ambala (Punjab) ; Dehra Dun, Saharanpur, Meerut, Bulandshahr, Budaun, Mainpuri, Etawah, Cawnpore and Unao (U. P.). Thus, breeding occurred as far as Unao (U. P.) in the East and N. W. F. Province in the West, and Sind, Baluchistan.

October.—During the first half of October locust situation in India was practically the same as in September with the only difference that while no ovipositions were recorded from Baluchistan, a few reports were received from Lyallpur and Shahpur in the Punjab, Mainpuri (U. P.) on 7th October and Hyderabad (Sind) on 5th October. In U. P. locusts had reached as far as Allahabad district and their direction of flight was from west to east.

Locust movements in the second fortnight of October are in many ways interesting. In U. P. the direction of swarms flight was mostly west

to east and by the end of the month they had spread as far east as Ghazipur and Gorakhpur districts. On the other hand, in the Punjab they had thinned down considerably, particularly, in the eastern part of the province.

Pink-coloured adults were present in Loralai and Kalat. These were freshly emerged. Eggs were reported from Kalat (Baluchistan) and Lyallpur (Punjab) and hoppers were reported from Kalat (Baluchistan), western districts of the Punjab and D. I. Khan district of N. W. F. Province.

November.—Situation was similar to that in the preceding fortnight. The following striking points may be mentioned :—

(1) Concentration of swarms in the western half of the Punjab and in eastern half of the United Provinces between Shahjahanpur and Ballia;

(ii) Concentration of swarms in north western parts of U. P., *i.e.*, Dehra Dun, Bijnore, Saharanpur, Almora, Garhwal and Nainital districts in the second half of the month;

(iii) The flight of swarms from U. P. towards Nepal, where they probably died ; and

(iv) Presence of swarms in Kotah (Rajputana) and Western India States.

Oviposition was recorded from Zhob (Baluchistan) on the 10th. A report of oviposition was also received from Ballia (U. P.) on the 18th, but this is doubtful. Hoppers were recorded from Kalat, Sibi, Loralai and Zhob (Baluchistan), Tharparkar (Sind), D. G. Khan, Mianwali, Jhang, Shahpur, Gujrat (Punjab), Saharanpur, Etah and Barabanki (U. P.). The last report was from Etah on 24th.

December.—During December locusts were present in Kalat, Sibi, Loralai (Baluchistan), Karachi, Hyderabad, upper Sind frontier ; Western India State ; D. G. Khan, Multan, Muzaffargarh, Mianwali, Attock, Shahpur, Jhang, Jhelum, Rawalpindi, Gujranwala, Sialkot, Amritsar, Gurdaspur, Kangra, Ambala, Gurgaon in the Punjab ; Bijnore, Garhwal and Almora in the U. P. It is striking that hoppers were recorded from Kalat (Baluchistan) on 16th and 28th in Shahpur (Punjab) and in Bijnore (U. P.) on 3rd. In Bijnore eggs were also recorded on 3rd. This report seems extremely doubtful.

VIII. LOCUST SITUATION IN 1930 (Plate VI).

Locust activity in India was at its maximum during 1930. Unlike the previous years the winter break in locust-movement was almost absent and even during the month of January reports of swarms visiting a fairly large number of places in Baluchistan, Sind, Rajputana, States of Western India, the Punjab and the United Provinces were received. It was for the first time that locust swarms were present in the United Provinces in January. This was probably because there was an extensive breeding of the desert locust within the United Provinces, particularly in the eastern part during the latter half of the previous year.

January.—Swarms were recorded from Loralai, Sibi and Kalat (Baluchistan) Sukkur, Upper Sind Frontier, Tharparkar and Larkana (Sind), Palanpur and Bhavanagar in Western India States, in Jaipur (Rajputana), in D. G. Khan, Multan, Montgomery, Mianwali, Jhelum, Shahpur, Attock, Rawalpindi, Gujrat, Jhang, Sialkote, Gurdaspur, Amritsar, Kangra, Hoshiarpur, Jullundur, Ludhiana, Ambala and Gurgaon districts of the Punjab and Dehra Dun, Garhwal, Almora, Nainital and Saharanpur districts of the United Provinces.

The only report of oviposition during January, was on the 26th, from Kalat (probably Mekran coastal area).

February.—During February, egg-laying continued in Kalat and Chagai (24th) and swarms were seen flying about in Kalat, Chagai, Quetta, Loralai, Sibi and Zhob in Baluchistan.

On the 29th February oviposition occurred in Sukkur and swarms were recorded throughout the month in Sukkur, Upper Sind Frontier, Tharparkar and Larkana districts of Sind.

The first oviposition of the year in the Punjab occurred on 3rd February in Attock, which was followed by profuse egg-laying in Rawalpindi, Jhelum, Gujrat, Sialkot, Gujranwala, Sheikhupura, Lyallpur, Muzaffargarh, Multan, Montgomery, Ferozepore, Hoshiarpur and Ambala districts. The south eastern districts of the province were free from locust, except Karnal which was invaded by locust swarms from Muzaffarnagar (U. P.).

In the United Provinces, the Desert locust was swarming in Kheri, Shahjahanpur, Farrukhabad and in all the western districts more or less adjoining the Punjab and a part of the Rajputana.

Eggs were reported from the Deoband tehsil of the Saharanpur district on 6th February and from Saharanpur (24th, 25th and 28th), Meerut (25th), Bulandshahr and Bijnore (21st). There is a report of the emergence of hoppers in Almora (U. P.) on 12th February. The report was made by the Deputy Commissioner, Almora, to the Entomologist, U.P., Cawnpore, and it reads thus: " Ranger Dewaldhar found hoppers underneath thick logers of *chir* (pine) needles and seedlings; he thinks locusts laid eggs under logers of fallen *chir* (pine) needles as there was no loose soil; area harmed was roughly 70 acres." Almora being hilly, is a comparatively cold place and the desert locust must have a prolonged incubation period there during the winter. Thus it appears that the eggs may have been laid in October-November, 1929 when the locust was concentrating in this district and hatched after a prolonged incubation period. If so it is an interesting fact.

March.—During March swarms were flying about in Zhob, Quetta, Kalat and Lasbela in Baluchistan and Jaipur, Jaisalmere and Almora states of Rajputana. Complete absence of reports of locust activity in Sind is a noteworthy feature of the month. Although most of the locust

swarms had concentrated in the eastern half of the Punjab and the western one-third of the United Provinces stray swarms were present in other parts of these provinces also. One of them reached as far east as Lucknow (U. P.) at the end of the month.

Oviposition was recorded from Baluchistan (Kalat and Chagai), Punjab, U. P. and Jammu (Kashmir State). The eastern most limit was Budaun (U.P.).

Hatchings were common during the month. On the 2nd March hoppers were recorded from Kalat (probably Mekran). Regarding the other tracts of Baluchistan hoppers were noticed in the first week of the month in Chagai and in the last week of the month in Zhob. In Sind, emergence of hoppers was recorded in the second week of March, in Baluchistan, in third and fourth weeks of the month and in the Punjab and the U. P., almost throughout the month in all the districts in which eggs had been laid during February.

April.—During the first fortnight of April locust position remained the same as in the second fortnight of March. In the second half of the month while reports of swarms of locust hoppers and of fresh emergence were as numerous as in the first half of the month from Mekran, Chagai (Baluchistan) ; Muzaffargarh, Multan, Montgomery, Jhang, Sheikhupura, Gujrat, Gurdaspur, Amritsar, Lahore, Hoshiarpur, Jullundar, Ludhiana, Ferozepore, Ambala, Karnal, Punjab States, Sirmur State, Bahawalpur State, and Dehra Dun, Bijnore and Meerut districts of the United Provinces, the reports of swarms of adult locusts as well of ovipositions were very scanty. Swarms were reported from Chagai (Baluchistan), Larkana, U. S. Frontier (Sind), Bahawalpur State, Gurgaon (Punjab) and Meerut (U. P.) and oviposition was reported from Mekran, Chagai (Baluchistan), Sheikhupura, Amritsar, Jullundur, Patiala, Karnal, Gurgaon (Punjab) and Meerut (U. P.).

May.—The presence of the Desert locust hoppers and fresh emergence of hoppers in Baluchistan (Chagai, Srawan, Mekran and Zhob) and the Punjab (from practically all the districts), continued to be reported upto the end of the month. In U. P. deposition of eggs was recorded on the 3rd May in the Dehra Dun, Saharanpur and Muzaffarnagar districts which lie beyond the eastern boundry of the Punjab.

Heavy oviposition occurred in Baluchistan, upto the 17th instant in Quetta and a little earlier in Mekran and Chagai. Oviposition occurred on 2nd and 5th in the Gurgaon and Karnal districts respectively. No oviposition was reported from the U. P. during the month.

The disposition of the swarms of fliers during May was interesting. During the first twenty days of the month swarms were present in parts of Baluchistan, Sind, Rajputana, Punjab and U. P. In U. P., Agra, Aligarh

and Bareilly marked their limit on the east. During the last ten days of the month the locust population seems to have increased enormously and locust swarms reached as far as Gorakhpur (U. P.), Gwalior (Narwar, Gird Gwalior and Bhind), and Central India (Indore, Orchha, Nagoda and Rewah). This was the first time that the desert locust swarmed into Gwalior and Central India during the 1926-31 invasion. The direction of flight of swarms in the U. P. was from west to east, which indicated that the province received fresh outbreaks of fliers of the spring brood from the Rajputana and the Punjab.

June.—During the first fortnight of June while in Baluchistan, Sind, Eastern boundry of N. W. F. Province, Rajputana and Gwaliar locust activity was well marked, there were fewer reports from the Punjab, the United Provinces and the Central India. The fliers were reported from Mianwali, Shahpur, Rawalpindi, Jhelum, Gujrat, Simla, Karnal and Gurgaon (Punjab), Meerut, Cawnpore, Jalaun, Jhansi, Hamirpur, Banda and Mirzapur (U. P.), and Nagod and Rewah (Central India). The general direction of flight of swarms in U. P. was from west to east and the swarms appear to have invaded the province from Rajputana side. During this fortnight eggs were recorded in Lasbela (10th) Sarawan, Jhalawan and Kachi (Baluchistan) and hoppers in Mekran (Baluchistan) only.

During the second fortnight of June locust population further decreased in the Punjab, swarms of fliers having been reported only from D. G. Khan, Muzaffargarh, Mianwali, Rawalpindi, Jind, Gurgaon and Bahawalpur State. On the other hand locust activity greatly increased in the United Provinces. Reports of swarms of fliers were received from all over the province, except a few north-western districts. Having infested the whole of the province locust swarms entered Bihar and Orissa and infested Shahabad, Palamau, Patna, Gaya and Ranchi districts. Oviposition during this fortnight was very scanty and was reported only from Bahawalpur and Alwar States.

July.—During the next three months *viz.*, July, August and September, 1930 the breeding of the Desert locust reached its zenith. Eggs and hoppers were reported from the eastern Punjab, from those districts of the United Provinces that lie adjacent to the Punjab, and Jodhpur, Bikaner, Jaipur, Bharatpur, Alwar and Dholpur states of Rajputana. It was in these regions that extensive breeding took place and it was from here that most of the swarms which were found elsewhere later on had migrated.

During July the swarms of locust infested practically the whole of Baluchistan, Sind, Rajputana, Punjab, N. W. F. Province, major portion of U. P., a few north western districts of Central India and Ranchi district of Bihar and Orissa.

In Baluchistan locust infestation was less intense than in the abovementioned parts of the country. In the western districts of the Punjab

locust problem was not so serious as in the eastern districts which were very heavily infested indeed. On 16th July a few swarms entered D. G. Khan from Sibi (Baluchistan) side.

Fliers of the desert locust were swarming all over the U. P. They were moving from east to west towards Rajputana in the first half of the month and continued vacating the eastern and southern half of the province so much so that by the end of the month they were reported only from Muzaffarnagar, Saharanpur and Bulandshahr districts.

In central India swarms were reported from Bhopal (3rd July) and Orchha (weak ending 12th). In Bihar and Orissa no reports were received after their visitation of the Ranchi district on 9th July.

During the first week of July ovipositions occurred in Baluchistan (Lasbela 1-7), Rajputana (Ajmere-Marwara 1.) and hoppers appeared in Lasbela (1-7) and Bahawalpur state (W. E.).

Intensive breeding continued on a large scale during the rest of July. Ovipositions were recorded in Mekran (11,29.), Lasbela (16, 2-31.) and Loralai (Baluchistan); Tharparkar, Hyderabad and Karachi (Sind), Jodhpur, Jaisalmer, Bikaner, Jaipur, Alwar, Bharatpur and Dholpur (Rajputana), east Punjab, parts of west Punjab (Shahpur, Montgomery and Lyallpur districts) and the Punjab states, Delhi, Saharanpur, Muzaffarnagar, Bijnore, Meerut, Bulandshahr, Aligarh, Muttra, Agra, Etah, Budaun, Moradabad, Bareilly, Shahjahanpur, Etawah, Jalaun and Cawnpore districts of U. P. Hatching started on a large scale on about the 20th July and by the end of the month the whole of the above-mentioned area was infested with hoppers.

August.—In August locust position in India was practically the same as in July. Hatchings were more numerous and breeding on an extensive scale occurred in north west Punjab also.

September.—During September 1930 swarms began to spread further south mostly from Rajputana and Southern districts of the United Provinces. During the first week of the month the southern most limit of the locust infested area was Palanpur (Western Indian States), Udaipur and Kotah (Rajputana) and Rewah (Central India). In the second week they travelled further south and were recorded from all over the Central India upto Indore and Ujjain. In the third week they reached Nimar, Hoshangabad, Betul and Akola districts of Central Provinces and in the last week of the month they reached as far south as Warangal district of Hyderabad (Deccan) on 28th. At the same time they were present in Akola, Nagpur, Betul and Hoshangabad districts of the Central Provinces. All through, generally, locust-movement was from north to south.

At the same time swarms also began to spread eastward in the U. P. and reached the eastern extremity of the province (Ballia district) on 8th

instant. From there they went further east and having crossed the provinces of Bihar and Orissa (unreported) they reached as far east as Rangpur district of north Bengal during the week ending 30th September. They were flying from south-west to north-east. Thus during this year locust swarms extended as far as Rangpur (North-Bengal) in the east and Warangal (Hyderabad-Deccan) in the south.

It is noteworthy that while throughout the month swarms were actively flying about in Rajputana, Sind and Baluchistan and during the first half of the month. in the U. P. their force was decreasing in the Punjab till at the end of the month no swarming was reported from the province. The same thing happened in the U. P. during the second fortnight and the last report was from Mainpuri district on 23rd September.

Oviposition and hoppers were not reported from beyond Lucknow (U. P.) on the east, Rawalpindi (Punjab) and Kalat (N. W. F. P.) on the north, Mekran (Baluchistan) on the west and Udaipur (Rajputana) on the south. Hoppers were reported from Mekran, Lasbela (Baluchistan), Kohat (N. W. F. P.), all over east Punjab and a few districts of north-west and west Punjab, Rajputana and in all the districts of U. P. adjoining the Punjab and a few others lying west of Lucknow.

It is noteworthy that in the Punjab ovipositions during the month were recorded mainly from the sub-montaenous districts; the south eastern Punjab remained practically free of eggs.

October.—During the first week of October Baluchistan and Sind, except Mekran and Loralai, where swarms were present, were free from all stages of locust.

In N. W. F. P. hoppers were present during the week ending 22nd instant in the Kohat district.

In the Punjab a few swarms were recorded in the Dera Ghazi Khan and Gurgaon districts only. Hoppers were present in Mianwali, Amritsar, Gurdaspur and Ferozepore and the Punjab states.

But for a report of egg-laying in Muzaffarnagar on 3rd October (which is the last available report of egg-laying during the year in U. P.) and presence of a swarm on the 1st in Bijnore, no locust of any stage was reported from the United Provinces.

In Rajputana swarms were recorded in comparatively greater numbers in Jodhpur, Jaipur, Bharatpur, Udaipur, Bundi, Kotah, Dungarpur. Eggs were reported from Jodhpur, and hoppers from Jodhpur, Bikaner and Dholpur.

From Rajputana locusts spread further South and infested the whole of the Western India States, Jhabua, Indore, Barwani, Mandasar, Bhopal in Central India, Tonwatgarh (Gwalior), Akola, Nagpur,

Jubbulpur, Mandla, Nimar and Buldana (Central Provinces) and Warangal (Hyderabad-Deccan).

In the east they were present in Ranchi, Sambalpur, Singhbhum, Manbhum (Bihar and Orissa), Dinajpur, Rangpur, Pabna (Bengal) and in Goalpara in Assam (21st October). No oviposition was recorded during the remaining three months of the year, with the solitary exception of Barwani (Central India) in November.

November.—During November only a few swarms were noticed in Baluchistan in the Sibi zone. In the Punjab only one swarm was recorded in Simla flying from south-east to north-west on 13th instant. There were no swarms in N. W. F. P. In U. P. a few swarms were noticed on 27th and 28th instant in the extreme South-Eastern corner of the province in the Mirzapur district.

In Rajputana locusts were active in Dholpur, Ajmere-Marwara, Jaisalmer, Jodhpur, Udaipur and Banswara.

Adjoining the southern boundaries of Rajputana and U. P. they were recorded in Jhalawar and Halar in West India States, in Ahmedabad, Nasik and Thana in Bombay presidency, in Jhabua and Rewah in Central India, and in Seoni, Jubbulpore and Mandla in the Central Provinces. Hoppers were noticed in Barwani (Central India).

In the east they were recorded in Palamau, Ranchi and Santal Parganas (Bihar and Orissa); Darjeeling, Jalpaiguri and Cooch-Behar in extreme north of Bengal and in Assam. Farther in the east they were found in Goalpara, Kamrup, Darrang and Sibsagar (Assam) in the end of the month. From Darrang they travelled north and in week ending 28th reached Balipara F. tract.

December.—During December locust swarms extended further towards the north-east in Assam along the Brahmaputra (river) and were noticed in Lakhimpur district on the 2nd, flying from south-west to north-east. Throughout the month they were active in Sibasagar while in the first ten days of the month they swarmed Balipara F. tract, Darring and Goalpara. They were reported from Monghyr, Ranchi, Palamau (Bihar and Orissa), Mirzapur (U. P.) and Rewah (Central India) but curiously enough there was no report from Bengal.

On the southern side the swarms probably died out and were reported during the week ending 1st December in Seoni (Central Provinces) and Palanpur, Sorath and Cutch (Western India States) and southern extremity of Jodhpur state (Rajputana). There was no locust activity recorded in Sind. The swarms that were present in large numbers in the previous month in Rajputana dispersed out of the area. A few of them entered western India states and others migrated into the Punjab states, Montgomery, Multan and Lyallpur districts of the Punjab during the

first fortnight of the month. There was a very doubtful report of egg-laying in Jodhpur (Rajputana) in the middle of the month. The swarms that were recorded in Simla (Punjab) during November migrated into Kangra and Hoshiarpur districts of the Punjab.

IX. Locust situation in 1931

The control measures employed against locust in 1930 in various provinces and specially in the Punjab undoubtedly reduced the population of the pest appreciably. A doubtful report of hatching on 18th March 1931 received from Chagai (Baluchistan) indicates that eggs must have been laid there in the beginning of February. It was during April that some swarms abruptly invaded Chagai from Afghanistan and Persia and spread over the whole of Baluchistan, Sind and Rajputana during the succeeding months. During March-April local swarms were also observed breeding in Lasbela (Baluchistan).

Western part of Punjab was invaded for the first time during June when a swarm entered D. G. Khan district on 20th. This swarm could only be traced upto Mianwali but no further.

South-east Punjab and west U. P. were invaded during the second week of July from Rajputana. Eggs were laid in these tracts but they were mostly destroyed. Breeding took place on a large scale during summer in Rajputana, but Sind and Baluchistan remained free. From September to December, 1931 swarming activity went down so much that during December only a few swarms were reported from Kalat (Baluchistan). This seems to be the end of the great locust invasion which started in 1926. We shall now give a detailed account of the visitation in India during 1931.

January.—In the beginning of January, 1931 a few locusts were recorded in Mirzapur—an extreme south-eastern district of U. P., Shahabad, Palamau and Gaya districts (Bihar and Orissa) and Palanpur, Halar and Cutch in States of Western India.

February.—During February only one swarm was reported from Jhalwar (States of Western India) on 1st instant.

March.—During March a swarm was reported from Multan (Punjab) on the 4th and hoppers were recorded in Chagai (Baluchistan) on 18th instant. This indicates that stray locust swarms were present in Chagai during February and they laid eggs.

April.—During April swarms invaded Chagai from Persia and spread further into Quetta and Kalat (Baluchistan) and entered U. S. Frontier district (Sind) on 17th instant from Kachi (Baluchistan). Eggs were laid in Chagai on 20th and 24th of the month, in Quetta on 1st and in Kalat (probably Mekran) on 24th instant. The presence of hoppers

in Lasbela during the month showed that eggs must have been laid there most likely by the local over-wintered adults during March.

May.—During May locusts were active in Baluchistan where they were recorded in Chagai, Mekran, Kharan, Jhalawan, Sarawan, Quetta, Lasbela and Loralai. In Lasbela their direction of flight was mostly from west to east. Loralai was invaded on 26th instant by the swarms which after passing unnoticed through D. G. Khan district flew from south to north and west to east into the Multan (Punjab) district on 29th instant. This time again it will be observed that the Punjab was invaded from Baluchistan through the south western corner of the province. A few swarms flying from south-east to north-west were recorded in the Agencies and Tribal areas adjoining the Kohat district in N. W. F. P. These swarms probably came from Kohat where breeding had occurred during summer 1930.

Eggs were laid in Chagai (5), Kharan(6), Quetta (6, 7, 10, 16), Sarawan (18), Lasbela (26) and Kharan (23), Mekran (8, 22, 27) and Sarawan (22, 26, 27) tracts of Baluchistan. A report of egg-laying in Jodhpur (Rajputana) on 4th instant indicates the presence of some local overwintered adults there.

June.—During June locust position in Baluchistan was the same as in May. Eggs were laid in Mekran on 8th and hoppers were present in Chagai, Sarawan and Mekran throughout the month. From Lasbela where the direction of flight of swarms was from west to east locusts further spread in Karachi, Larkana, and Nawabshah districts of Sind. From Larkana they went upto Upper Sind Frontier and entered the Rajanpur tehsil of D. G. Khan (Punjab) on 20th instant. Later on they travelled upto Mianwali; where they were noticed flying from west to east on 22nd instant. A report of swarms flying from east to west in Ludhiana (Punjab) on 15th instant is interesting. Probably it was a local swarm. In Rajputana locusts were recorded in Jaisalmer, Jodhpur, Ajmer-Marwara, Dungarpur, Banswara all through the month and ovipositions were recorded in Jodhpur on 11th instant. A swarm noticed in Halar (Western India States) on 27th instant flying from south to north was probably a stray remnants of January, 1930 swarms. In the Agencies and Tribal areas of N. W. F. P. swarms were noticed flying from west to east on 18, 24 and 30th instants. They probably came from the Afghanistan.

July.—During July, with the exception of Lasbela and Chagai tracts, locusts were present all over Baluchistan. Loralai, Sibi and Kachi tracts were very badly infested, and as the direction of flight of swarms in these tracts was mostly from east to west in the first fortnight of the month they probably originated from D. G. Khan (Punjab) where they were noticed in very large numbers during the second fortnight of the month.

In Baluchistan eggs were laid in Quetta (6) and hoppers were observed in Mekran (3,15).

The whole of Sind and Bahawalpur State and Jaisalmer, Jodhpur, Bikaner, Ajmere-Marwara, Sirchi, Jaipur and Karauli states of Rajputana were badly infested. Eggs were laid in Jodhpur on 11th, Jaisalmer on 23rd and Bahawalpur on 30th.

In the Punjab and the United Provinces, however, locust position was very interesting because, whereas these provinces were entirely free from the pest in the first half of the year locusts abruptly invaded them in very large numbers on about the 10th of July from Rajputana and after spreading over the east Punjab and west U. P. gradually went further and by the 18th of the month had reached Gurgaon, Hissar, Punjab States, Rohtak, Karnal, Ludhiana, Ferozepore, Lahore, Sheikhupura and Lyallpur districts of the former province and Agra, Mainpuri, Muttra, Aligarh, Etah, Hardoi, Shahjahanpur, Budaun, Moradabad, Bulandshahr, Meerut, Muzaffarnagar, Saharanpur and Bijnore districts of the latter province. Delhi was also infested. Eggs were laid in the above districts. The earliest report came from Aligarh on 10th July. In the east Punjab the eggs were first laid in Gurgaon on 13th July. Hoppers were recorded only in Gurgaon (Punjab) on 27th and Aligarh (U. P.) on 25th instant.

In the west Punjab, however, conditions were different. First swarm was observed in D. G. Khan on 11th July. The presence of hoppers in D. G. Khan on 28th July suggests egg-laying in that district on about the 13th of July. From D. G. Khan, they invaded the Muzaffargarh district on 19th July. The swarms that visited Mianwali on 17th, 18th and 24th July from north-east and flew to south-west were probably of local origin and those that visited the Montgomery and Multan districts on 29th July probably came from Bahawalpur side.

August.—During August locust activity went down in the country. No breeding took place in Baluchistan; swarms were recorded in Lasbela, Kalat, Sibi, Loralai and Zhob (Baluchistan), Karachi, Nawabshah and U. S. Frontier district (Sind) Bahawalpur State, Jaisalmer, Jodhpur, Bikaner, Ajmere-Merwara, Jaipur, Dholpur states of Rajputana; Dehra Dun, Meerut, Bulandshahr, Budaun and Mainpuri districts of the United Provinces and D. G. Khan (where they were very active), Muzaffargarh, Multan, Jhang, Lyallpur, Multan, Montgomery, Lahore, Ludhiana, Ferozepore, Punjab States, Hissar and the Gurgaon district of the Punjab.

Eggs were recorded from Jodhpur (W. E.* 15, 22, 30), Jaisalmer (W. E. 15, 25 and 27), Ajmer (6, 12, 17 and W. E. 22) in Rajputana, Bulandshahr (16) in the United Provinces, Hissar (5, 8, 11, 14), Ferozepore (9, 13, 17, 19), Ludhiana (7, 17) in the Punjab and D. G. Khan (10) and

* W. E.—week ending.

Punjab states (10) in the Punjab. Hoppers were noticed in Jodhpur, Jaisalmer, Ajmer-Merwara and Bikaner in Rajputana, Gurgaon, Hissar, Ferozepore, Ludhiana, Montgomery and D. G. Khan in the Punjab. The last date of the presence of hoppers in the Punjab was in the week ending 30th (Hissar).

September.—During September swarms were present in Baluchistan (Kalat, probably Mekran region, Sarawan, Loralai, Zhob, Jhalawan and Lasbela), Sind (Larkana, Karachi, Nawabshah and Tharparkar districts), and states of western India (Jhalawan, 25th). In Rajputana they had concentrated in Jodhpur and Jaisalmer states and were also recorded in week ending 5th September in Alwar state. In the Punjab they were recorded only upto the 11th in D. G. Khan, Lyallpur, Jhang. Mianwali, Ferozepore, Gujranwala and Sialkot districts, but after that date they were only recorded in Gurdaspur on 29th instant.

Eggs were laid in Jodhpur (W. E. 12), Rajputana, Nabha (Punjab states) and Karachi (Sind). Hoppers were reported from Mekran (Baluchistan), Tharparkar (Sind), Jodhpur, Jaisalmer and Alwar (Rajputana).

October.—During October locusts were mostly absent from the Punjab. They were, however, recorded from the Chamba state (where they had most probably come from the Gurdaspur district) on 7th and 8th October, flying from north-west to south-east; and from D. G. Khan on 29th flying from north to south. They were reported from Rajputana (Jaisalmer), states of western India (Palanpur, Sorath and Cutch), Sind (Sukkur, Tharparkar, Hyderabad, Nawabshah, Larkana and Karachi) and Baluchistan (Kalat). Hoppers were noticed in Jaisalmer (Rajputana) during the week ending 24th October.

November.—During November, Bundi, Sirohi, Jodhpur, Jaisalmere (Rajputana), Palanpur, (states of western India), Sukkur, Tharparkar, Hyderabad, Nawabshah, Larkana, Karachi (Sind), Lasbela, Pasni, (Mekran) Turbat and Mashkai (Baluchistan) reported locust fliers.

December.—During December fliers were present in the central and western Kalat (Baluchistan).

X. LOCUST POSITION AFTER 1931

We have already observed that locust campaign was successfully carried out in India during 1931 and consequently in December of that year locusts were only recorded in central and western Kalat; with this the mass swarming that had started towards the close of 1926 and had continued during the next five years (1927-1931) came to an end. After 1931 as indicated in the table given below only a few stray individuals or swarms were reported in 1932, from a few localities in Baluchistan, Sind, Rajputana states and the Punjab. The survey parties of the Locust

Research Scheme also observed some individuals of the solitary phase breeding in Mekran (Baluchistan) in 1932.

Table showing movements of swarms in India in 1932

District	*January*	*February*	*May*	*June*	*August*	*Septembe*
Baluchistan						
Mekran	18	—	24 (stray specimens	—	—	—
Lasbella	—	End	—	—	—	—
Sind						
Karachi	—	—	—	Some black coloured fliers	—	—
States						
Palanpur	—	—	—	18,20	—	—
Western Kathiawar Agency	—	—	—	18	—	—
Jaisalmer	—	—	—	—	—	Small swarms reported by zamindars
Punjab						
Ferozepore	—	—	—	—	26	—

After 1932 the survey parties under the Locust Research Entomologist, Karachi, have recorded locusts of the solitary phase along the banks of Indus from Dera Ghazi Khan (in the Punjab) to Karachi, and many parts of Sind particularly Khairpur state and Tharparkar, in parts of Bahawalpur state and in some of Rajputana states and parts of South Baluchistan and Lasbela and all along the Mekran coast.

It will not be out of place to mention that it is not only the above-mentioned tracts which control the locust situation in India, but the breeding grounds in Persia and Arabia are equally dangerous, as it is just possible that breeding on a very large scale may start in those countries earlier than in India and swarms may consequently rush in suddenly from there into Baluchistan and N. W. India. This suggests that we must keep ourselves well informed about the locust movement in the neighbouring countries specially Persia and Arabia.

In this respect it is fortunate that the Locust Control Committee under the United Kingdom Economic Advisory Council has made good progress in gathering locust intelligence from various parts of the world and in communicating it to all concerned. I do feel that although there is a marked improvement in India in the supply of information of locust visitations yet it will not be possible to definitely trace out the origin of swarms appearing in certain localities and to follow their movements unless accuracy is insisted upon. It is further suggested that a system of village to village record be established. Problems such as the speed of the

movement of swarms, routes followed and meteorological factors involved can only be studied when full facts are available.

XI. RESUME OF LOCUST SITUATION IN INDIA, 1926-31

The extensive desert belt comprising the North West India (Baluchistan, Sind and Rajputana), Iran and Arabia is one of the permanent homes of the desert locust of phase solitaria (*Schistocerca gregaria* Forsk), but when the climatic conditions are suitable for multiplication, *e.g.* timely and good rainfall resulting in abundance of vegetation, in any one of these tracts they breed enormously, form swarms and fly at first in and about the region of their birth and with further increase in their number they invade the neighbouring tracts as well. This happened in North West India during the period 1920-26. Individuals of the solitary phase are known to have been breeding in the '*reks*' of Baluchistan during 1920-23 and with the advent of favourable season, to form small swarms within Baluchistan in 1923-25. In January, 1926 there was good rainfall and ample vegetation in this region (Rao, 1933) resulting in mass breeding and formation of swarms which spread further east in Sind and Rajputana in the summer of that year (June) and from there invaded south-west Punjab in December, 1926. In January, 1927 a few swarms entered south-east Punjab from Rajputana side and in the next few months spread over east Punjab and west U. P. In June, 1927 they went as far east as Muzaffarnagar, Palamau and Shahabad districts of Bihar and Orissa. In this manner swarming from the permanent breeding grounds to the other province of northern India continued for five successive years (1926-31).

Noskov (1928), Moritz (1928), Fletcher (1931) etc. have recorded evidence to show that in the winter of 1926-27, overwintering desert locust migrated from Baluchistan to Iran and bred there. On the other hand, for 1927 and 1931 it has been recorded that during the spring the desert locust migrated from Iran to Baluchistan. Instances like these clearly show how interdependent India and the adjoining tracts of Iran and Afghanistan are in dealing with locust problems. Therefore, in considering locust situation in India it is necessary to take into account the climatic conditions and locust situation in Iran also. Since a similar interdependence exists between Iran and Arabia locust situation in Arabia must equally concern us.

As observed above the 'centre of outbreak' of the last invasion in India (1926-31) was the coastal region of Baluchistan where there were incipient swarms as early as 1923. By 1925 they were swarming all over Kalat and Sibi (Baluchistan) and were observed breeding in Dera Ghazi Khan (Punjab). In January 1926 Mekran received heavy precipitation and locusts multiplied there. Same thing happened in Kachhi tract during spring 1926 (Rao, 1933). The swarms of fliers migrated eastwards

and spread over Lasbela, Karachi, Tharparkar and Jodhpur during July-October and bred there. Adults of the next generation, *i.e.* the summer brood, travelled south from Tharparkar (Sind) and Jodhpur (Rajputana) and invaded states of western India in November 1926. On the northern side they were swarming in Sibi and Loralai during November and from Sibi invaded the Punjab in December through its south-western corner, *i.e.* D. G. Khan district. These swarms having augmented the number of fliers indigenous to D. G. Khan swarmed into Loralai (Baluchistan) during December, 1926 and west and central Punjab during January, 1927. The Mekran swarms invaded Chagai during December and must have travelled farther and entered Iran during winter (1926-27), where they were noticed breeding during the spring of 1927.

The eastern Punjab was invaded through its southernmost corner (Gurgaon district) in the end of January, 1927, most probably from Rajputana side, and by the beginning of March these swarms travelled as far north as Ambala (Punjab), Sirmur State and Dehra Dun (U. P.) where they started breeding.

West Punjab received fresh swarms from Sind on 1st February, again through Dera Ghazi Khan district.

Overwintering adults concentrated during January in Chagai, Quetta, Kalat etc. in Baluchistan and bred there profusely during spring of 1927.

In June 1927, swarms reached as far east as Bihar (Muzaffarpur 86°E) and swarmed over that province during July.

Thus the outbreak that originated in Mekran in the spring of 1926 spread in all directions, reaching Hazara (34°N) in the N. W. F. P. in January 1927 in the north, States of Western India (22°N) in November 1926 in the south, Iran (62°E) in winter 1926-27 in the west, and Bihar in June 1927 in the east.

In the latter half of 1927, the locust bred mainly in south-east Punjab and Sind. Between September 1927 and March 1928 locust activity had dwindled down to such an extent that during that period we heard of locust activity only from coastal regions of Baluchistan and Sind. Eggs were laid in Mekran in January 1928. Unfortunately, at this time Iran was heavily infested with swarms, a number of which invaded Baluchistan through Chagai as far as Sibi. They entered the Punjab through D. G. Khan district in the last week of April. by the end of May the whole of the Punjab and north-west parts ef U. P. (31°N. 80°E) were thoroughly infested. During the spring the locust bred in Baluchistan and west Punjab only. This spring brood of Baluchistan having acquired wings swarmed eastwards in June and invaded Sind. During summer (1928) breeding was reported only from south-east Punjab. From August upto the end of 1928 only

a few locust swarms were reported from the Punjab, namely, from Montgomery and Multan districts in November and Attock district in December. Locust was, however, active in Baluchistan and Sind from September to November.

This state of comparative inactivity of the locust continued upto the end of March, 1929. During these three months the only reports were : during January from D. G. Khan, Shahpur (Punjab) and Kalat (Baluchistan), during February from Sibi (Baluchistan) and during March from Kalat, Quetta and Zhob (Baluchistan). Intensive activity began in April, when the locust, after spreading over the whole of Baluchistan, invaded the Punjab through the D. G. Khan district, and by the end of the month spread over the whole of the province and even reached as far east as some north-western districts of the U. P. (80°E). During January-April, 1929 the locust bred in Baluchistan, west Punjab and Bharatpur (Rajputana). Like the previous year locust from the Baluchistan swarmed into Sind in June.

During summer of 1929 heavy breeding took place at numerous places in Baluchistan, Punjab, Rajputana and west half of the U. P. The adults that acquired wings in October spread further towards east from western U. P. and Rajputana during October-November, reaching as far as Ballia district (84° E) in Bihar. However, they could not survive long there. While during December, western U. P., Punjab, Sind, Baluchistan and States of Western India were heavily infested with locusts, there was no swarming or breeding in eastern U. P.

During January 1930 locust situation continued to be as serious as in December 1929, but breeding was restricted to Mekran coast. During the following month breeding was more extensive. Ovipositions occurred in Baluchistan, Sind, west Punjab and west U. P. March to June witnessed a further extension of locust invasion area towards the east, so that in June the Province of Bihar was also locust infested. During July, the Punjab received fresh swarms from Sibi, and Central India from the adjoining provinces, while on the other hand the U. P. and Bihar were almost free from locust swarms. Further movements of the locust swarms towards the east took place in September when they flew over Bihar and Bengal and reached Goalpara (Assam) in October, Sibsagar (Assam) in November and touched the north-eastern extremity of Assam at Lakhimpur (95°E) in December. During the whole swarming cycle (1926-31) it was only during these months that the swarms invaded Bengal and Assam. They were not able to breed here.

The intensive breeding that took place in Rajputana and the United Provinces during the spring of 1930 resulted in huge swarms many of which took southernly direction during July and invaded Central India and the

Central Provinces. By August the swarms extended as far south as Warangal (18°N, 80°E, Hyderabad—Deccan). In the succeeding months swarms that had entered into the inhospitable regions lying south of Rajputana died out without breeding. Thus during December we had report of locust swarms only from Seoni (C. P.) and some States of Western India.

The Punjab and the United Provinces were practically free from locust menace during September, and Sind and Baluchistan during October. In Rajputana, however, locusts were present throughout the year except during December when they migrated wholesale to States of western India and the Punjab. Thus in January, 1931 we find Rajputana completely free from locust swarms.

During the spring of 1931 locust activity was extremely poor. During January reports of stray swarms were received from Bihar, the United Provinces and the Central Provinces and western India ; during February from Western India only ; and in March only from Montgomery district of the Punjab.

In 1931 locust activity really commenced in April. A few local swarms were reported from Lasbela, while Chagai received fresh locust invasion from Iran and Afghanistan sides. In the succeeding months the swarms spread over the whole of Baluchistan, Sind and Rajputana. West Punjab was invaded in June through D. G. Khan district. It was a very mild invasion and the locust bred only in D. G. Khan and Montgomery districts. The eastern Punjab and western U. P. received swarms from Rajputana during July where they heavily oviposited. Luckily campaign against locust was in full swing by now and most of the eggs were destroyed. Their progeny was therefore not numerous. During summer of 1931, reports of intensive breeding were received from Rajputana, while there was no breeding in Sind and Baluchistan. From September onwards we heard very little of locust activity. In December a swarm was reported from Kalat only. During 1932 no regular locust invasion or movement of swarms was reported. Only from a few localitis in Baluchistan, Sind, Rajputana and the Punjab we had reports of stray swarms, which were remnants of swarms of the previous year.

Conclusions

From the observations recorded in this report the following important conclusions may be stated and it is suggested that special attention be paid during the next invasion to confirm these conclusions.

The flying swarms are capable of visiting the far off corners of India. During the last invasions swarms went as far east as Lakhimpur (Assam), as far south as Warangal (Hyderabad), but no eggs were laid and no hatching of hoppers reported from beyond Barabanki, Lucknow in the east and

Jhansi, Palanpur in the south. The statement attached gives extreme limits of oviposition, hatching and swarming in India during different years.

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Extreme limits of (

Period	Limits of direction	EGGS
		Locality
Aug.-Nov. 1926.	West	Lasbela (25°.5N ; 65-67°E)
	East	..
	North	..
	South	..
Dec. 1926-May 1927	West	Mianwali (31-33°; 71°.5E)
	East	D. Dun (30°N; 78°E)
	North	Hazara (34°.5N; 73°E)
	South	Gurgaon 28°N; 77°E)
June-Nov. 1927	West	Karachi (26-26°N; 67-68°E
	East	D. Dun (30°N; 78°E)
	North	Jullundur (31°N; 76°E)
	South	Karachi (24-26°N; 67-68°E
Dec. 1927-May 1928	West	Mekran (26°N; 62-65°E)
	East	Gujrat (32°.5N; 74°E)
	North	Attock (33°N; 72°E)
	South	Mekran (26°N; 62-65°E)
		M. Garh (29-31°N; 71-72°]
June-Nov. 1928	West	Jullundur (31°N; 76°E)
	East	..
	North	..
	South	Hisar (29-30°N; 75-76°E)
Dec. 1928-May 1929	West	Jhang (31°N; 72°.5E)
		Shahpur (32°N; 72.5E)
	East	Simla (31°N; 77°E)
	North	Attock (33°N; 72°E)
	South	Jhang (31°N; 72°.5E)

The statement attached gives extreme
and swarming in India during different

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	South	Hisar (29-30°N; 75-76°E)
Dec. 1928-May 1929	West	Jhang (31°N; 72°.5E)
		Shahpur (32°N; 72.5E)
	East	Simla (31°N; 77°E)
	North	Attock (33°N; 72°E)
	South	Jhang (31°N; 72°.5E)
June-Nov. 1929	West	Mekran (26°N; 62-65°E)
	East	Ballia (26°N; 84°E)
	North	Attock (33°N; 32°E)
	South	Hyderabad (Sind) (25°N; 69 E)
Dec. 1929-May 1930	West	Sarwan (29.5°N; 66.5°E)
	East	Mainpuri (27°N; 79°E)
	North	R. Pindi (35.5°N; 73°E)
	South	Ajmere Merwara (26°N; 75°E)
June-Nov. 1930	West	Jhalwan (25-29°N; 65-67°E)
	East	Lucknow (27°N; 81°E)
	North	R. Pindi (33°.5N; 73°E)
	South	Palanpur (24°N; 72°E)
Dec. 1930-May 1931	West	Chagai (28-29°N; 62-66°E)
	East	..
	North	..
	South	..
June-Dec. 1931	West	Jhalwan (25-29°N; 65-67°E)
		Sarwan (29-5°N, 66-5°E)
	East	Agra (27°N; 78°E)
	North	T. Territory (32-36°N; 70-73°E)
	South	A. Merwara (26°N; 75°E)

Appendix I

osition, hatching and swarming of locust in India from 1926—1931

	HOPPERS		ADULTS	
Months	Locality	Months	Locality	Months
Oct.	Lasbela (25°.5N; 65-67°E)	Oct.-Nov.	Lasbela (25°. 5N ; 65-67°E)	Aug.-Nov.
..	..	..	Palanpur (24°N ; 72°E).	November
..	..	..	Nawabshah (25°.5-27°N; 68°.5E	November
..	..	..	Halar (22°N; 71°E)	November
March April	Mianwali (31-33° ; 71°.5E)	March-May	Lasbela (25°.5N; 65-67°E)	March-May
March	D. Dun (31°N; 78°E)	April-May	D. Dun (30°N; 78°E)	April-May
March	R. Pindi (33°.5N; 73°E)	March-May	Hazara (34°.5N ; 73°E)	Feb.-May
April ?	Gurgaon (28°N; 77°E)	April	Sorath (21°. 5N; 70°.5E)	Dec.-January
June-July	Karachi (24-26°N; 67-68°E)	July-August	Lasbela (25°.5N; 65-67°E)	June-Aug.; Oct.
June	D. Dun (30°N; 78°E)	June	Bhagalpur (24°.5-26.5°N; 87°E)	July
Aug.	Hazara (34.5°N; 73°E)	June	Hazara (34.5°N ; 73°E)	June
June-July	Karachi (24-26°N; 67-68°E)	July	Halar (22°N; 71°E)	November
?	M. Garh (29-31°N; 71-72°E)	May	Mekran (26°N; 62-65°E)	?
April-May ?	Gujrat (32°.5N; 74°E)	May	P. Garhwal (30.5°N; 79.5°E)	May
May	Attock (33°N; 72°E)	May	Attock (33°N; 72°E)	April-May
? April-May	M. Garh (29-31°N; 71-72°E)	May	Kohelwar (21.5°N ; 72°E)	March
July	..	..	Lasbela (25°.5N ; 65-67°E)	July
..	..	..	Almora (29-30°N ; 72-81°E)	June
..	..	..	R. Pindi (33°.5N ; 73°E)	June-July
July-August	..	..	Karachi (24-26°N ; 76-78°E)	June-Oct.
April March-April	Attock (33°N; 72°E)	May	D.G. Khan (28.5-31.5°N; 70.5°E)	Jan.April; June
May	Shahpur (32°N; 72°.5E)	April	P. Garhwal (30°.5N ; 79°. 5E)	April; May
April-May	Attock (33°N; 72°E)	May	Hazara (34°.5N ; 73°E)	May
April	Shahpur (32°N; 72.5°)	April	Hissar (29-30°N); J5-76°E)	May
October	Hyderabad (Sind); (25°N; 69E)	Sept.	Mekran (26°N ; 62-65°E)	October
Nov.	Barabanki (27°N; 81°E)	Nov.	Ballia(26 ; (26°N ; 84°E)	November
Aug.-Sept.	R. Pindi (33.5°N; 73°E)	Sept.	R. Pindi (33.5°N ; 73°E)	Aug.-November
Sept.-Oct.	Hyderabad (Sind) (25°N; 69°E)	Oct. Sept.	Sorath (21.5°N . 70.5°E)	Oct.-November
April-May ?	Sarwan (29.5°N; 66.5°E)	May	Chagai (28-29°N; 62-66°E)	April
April	Mainpuri (27°N; 79°E)	April	Gorakhpur (26.5°N; 84°E)	May
Feb.	Attock (33°N; 72°E;)	May	R. Pindi (35°.5N; 73°E)	Dec.-Jan.-May
May	Mainpuri (27°N; 79°E)	April	Kohelwar (21°.5N; 72°E)	December
June	Lasbela (25°.5N; 65-67°E)	Aug.	Mekran (26°N; 62-65°E)	Sept.-Oct.
Aug.	Lucknow (27°N; 81°E)	Aug.	Sibsagar (26°.5N; 94°E)	November
Aug.	R. Pindi (33°.5N; 73°E)	Aug.	T. Territory (32-36°N; 70-73°E)	July-Aug.
Sept.	Palanpur (24°N; 72°E)	Sept.	Warangal (17°.5N; 80°E) (Hyd.-Deccan)	Sept.-Oct.
March	Chagai (28-29°N. 62-66°E)	March	Mekran (26°N; 62-65°E) Chagai (28-29°N; 62-66°E) Kharan (27-29°N; 63-66°E)	April-May
			Lakhmipur (27°.5N; 95°.5E) (Assam)	December
..	..	..	T. Territory (32-36°N; 70-73°E)	May
..	..	..	Sorath (21.5°N; 70.5°E)	December
June.	Jhalwan (25-29°N; 65-67°E)	June-July	Chagai (28-29°N; 62-66°E)	June-Dec.
July ?	Sarwan (29-5°N; 66-5°E)	July	Mekran (26°N; 62-65°E)	Jun.-Aug.-Nov.
July ?	Agra (27°N; 78°E)	July	Hardoi (27°N; 80°E)	July
Aug.	T. Territory (32-36°N; 70-73°E)	Aug.	T. Territory (32-36°N; 70-73°E)	June
Dec.	A. Merwara (26°; 75°E)	Sept.	Sorath (21°.5N; 70°.5;E)	October

APPENDIX II

Limits of oviposition, hatching and swarming of locust in India during the swarming period 1926-1931

North

Eggs, Hoppers, Adults — Tribal territory

West — Eggs, Hoppers, Adults — Mekran & Chagai

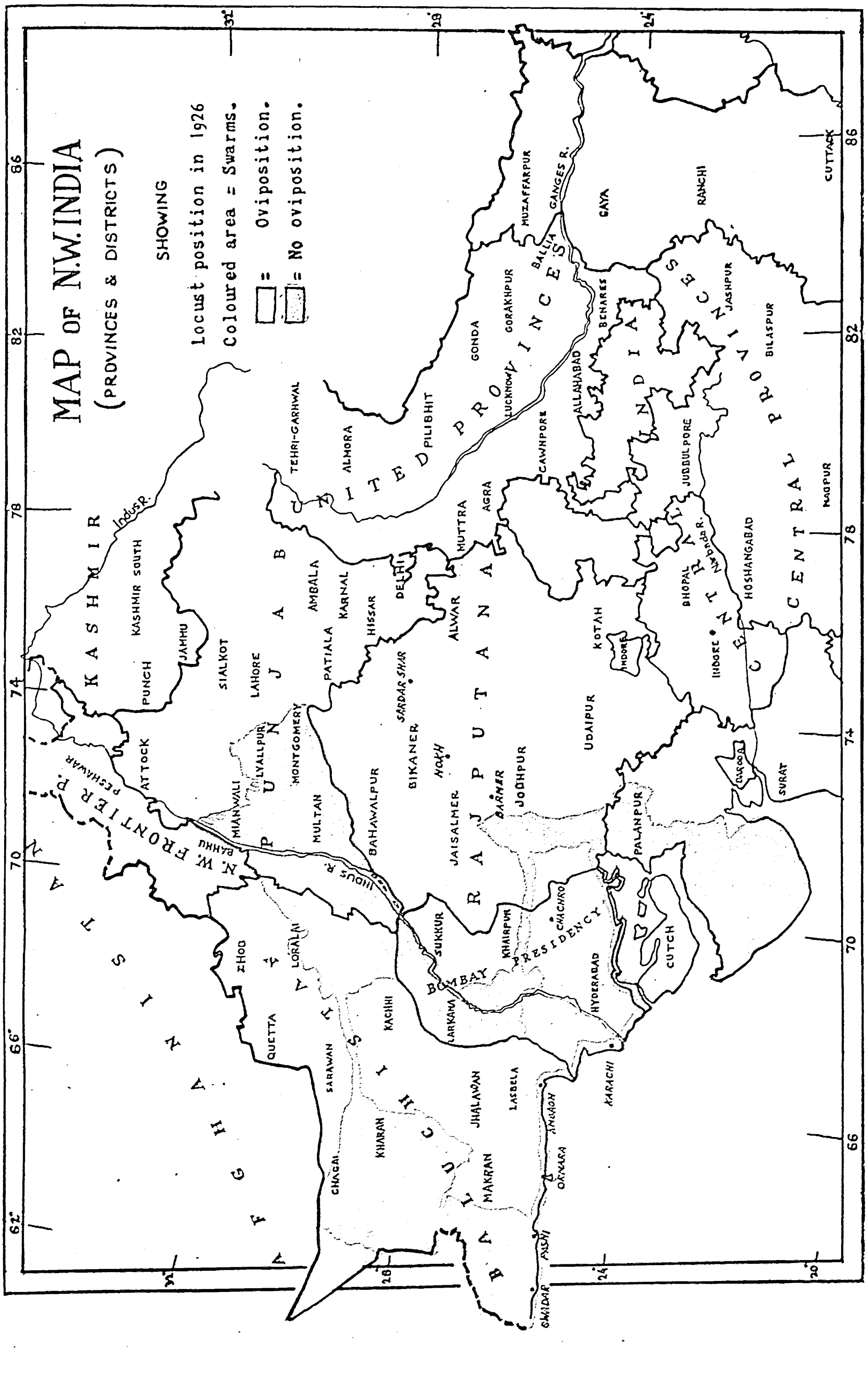
Ballia* — Eggs
Lucknow — Hoppers
Lakhimpur — Adults — **East**

Eggs, Hoppers, Adults — Palanpur (States of Western India) — Warangal (Hyderabad-Deccan)

South

* Report of ocust eggs in Ballia (U. P.). *in lit.* 18.xi.29, from Collector Ballia to Entomologist. 'A swarm of locust reached Sikandarpur and a number of locust stayed behind in the neighbourhood. *Some eggs have been found.*'

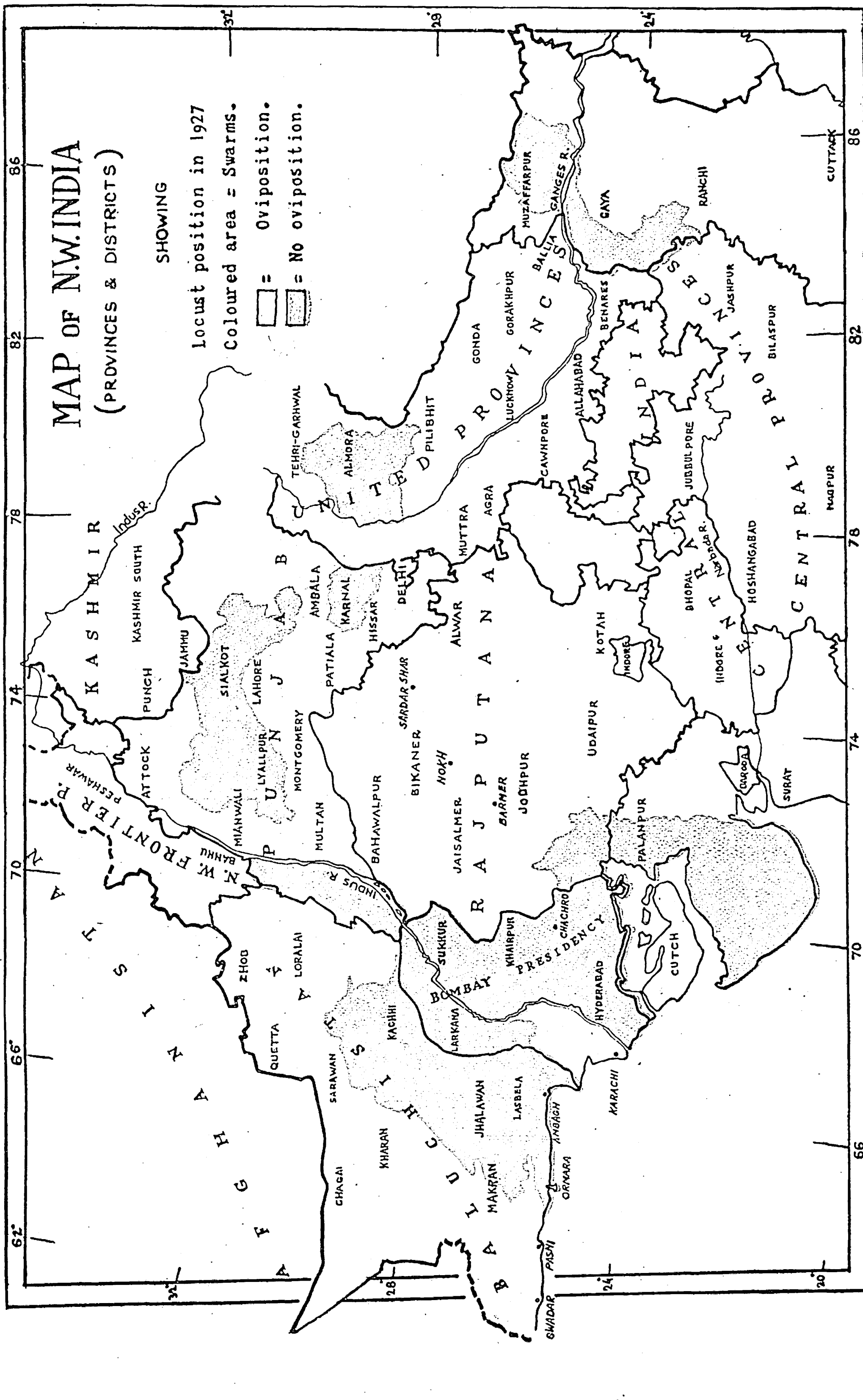
LOCUST SITUATION IN INDIA IN 1926



Names of districts in romans, names of localities in italics

Plate II

LOCUST SITUATION IN INDIA IN 1927



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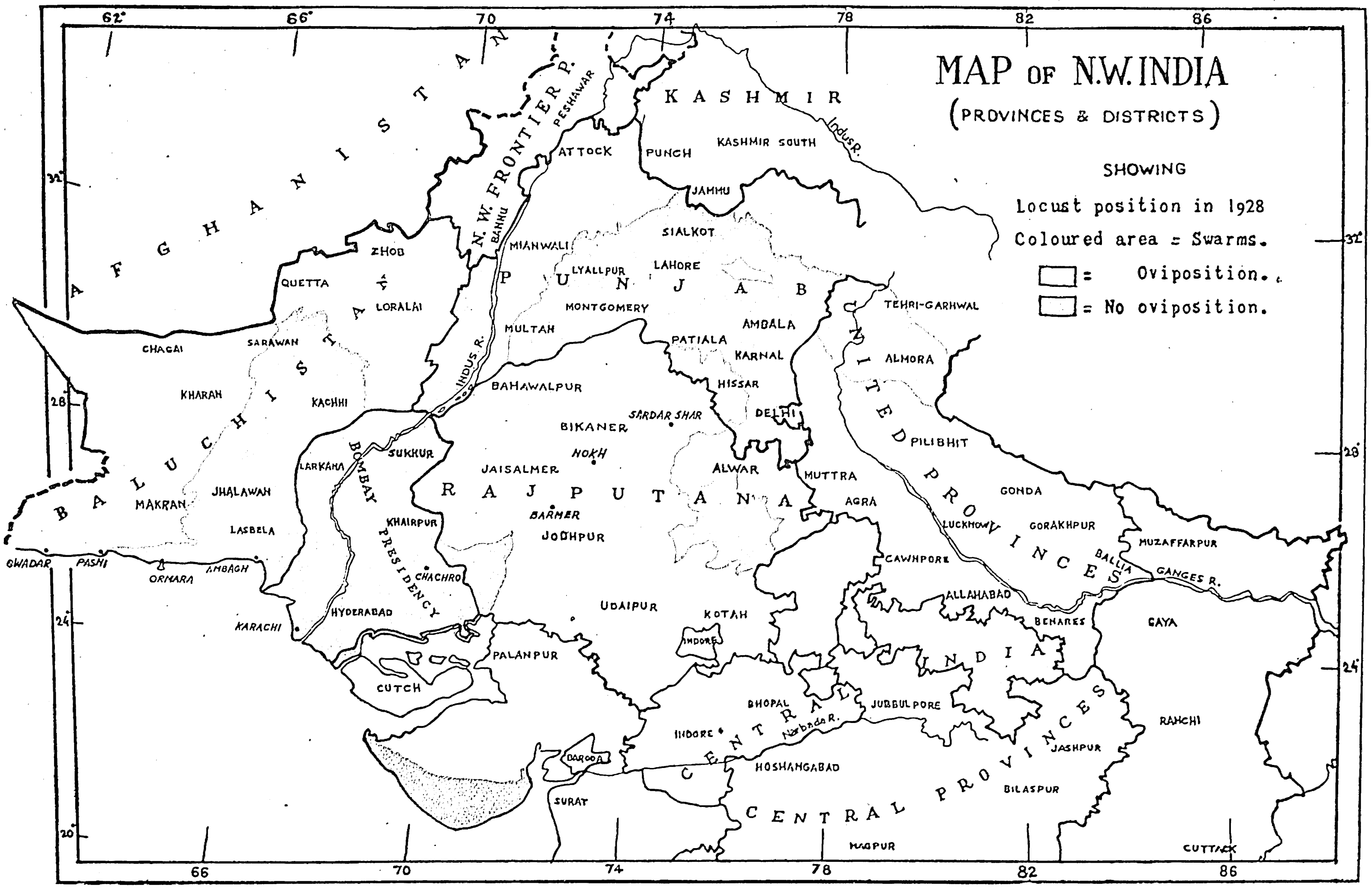
LOCUST SITUATION IN INDIA IN 1928



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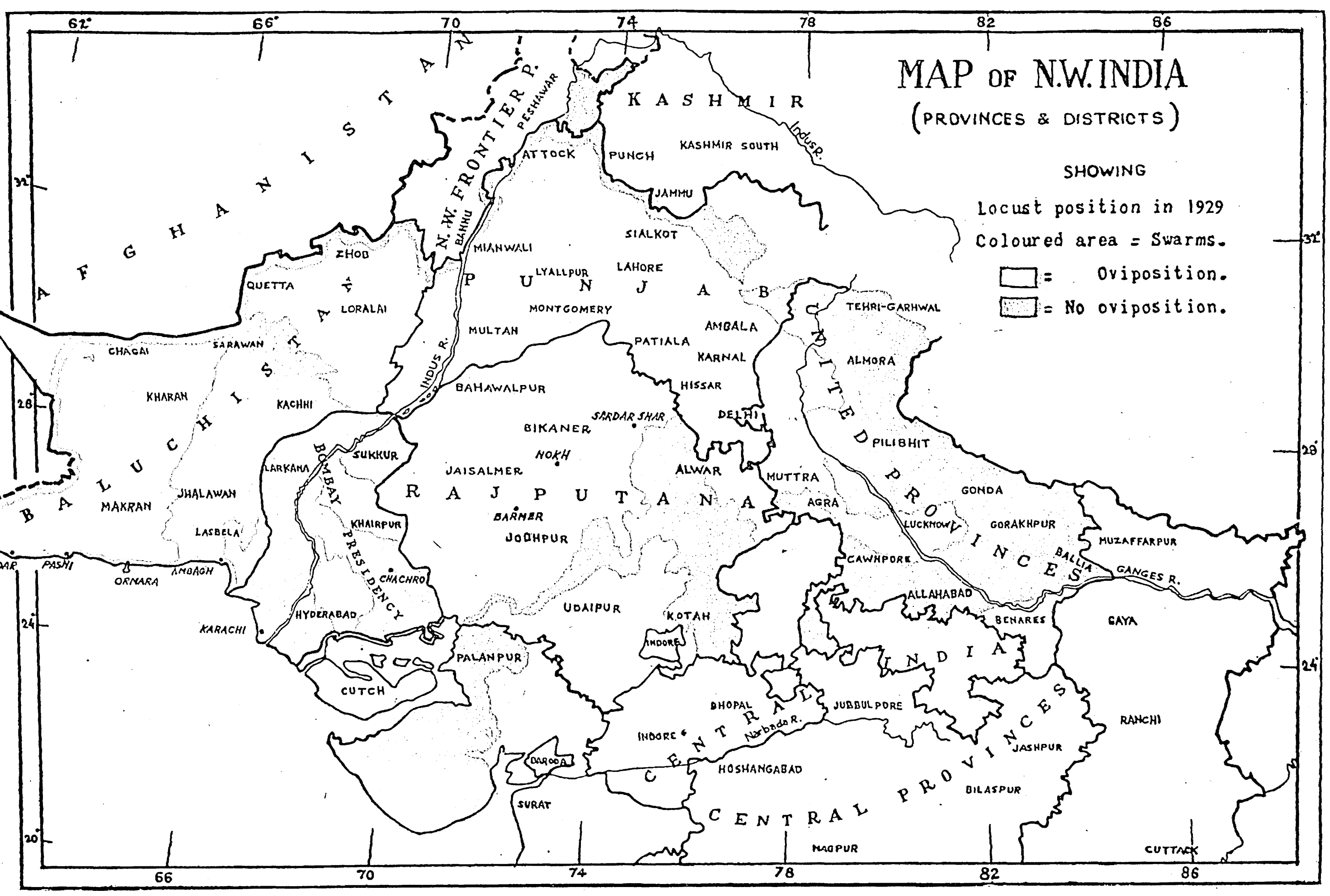
LOCUST SITUATION IN INDIA IN 1929



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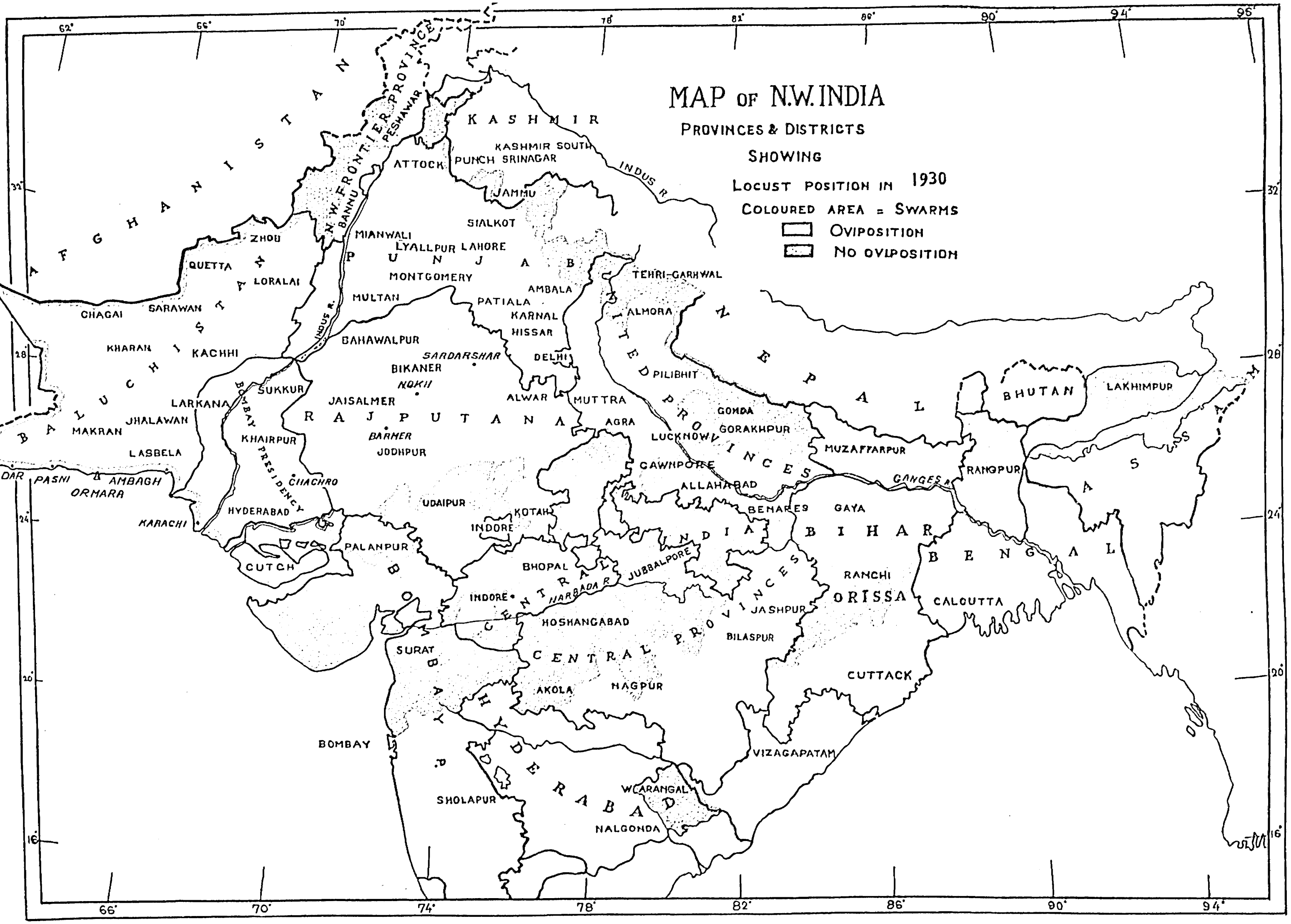
LOCUST SITUATION IN INDIA IN 1930



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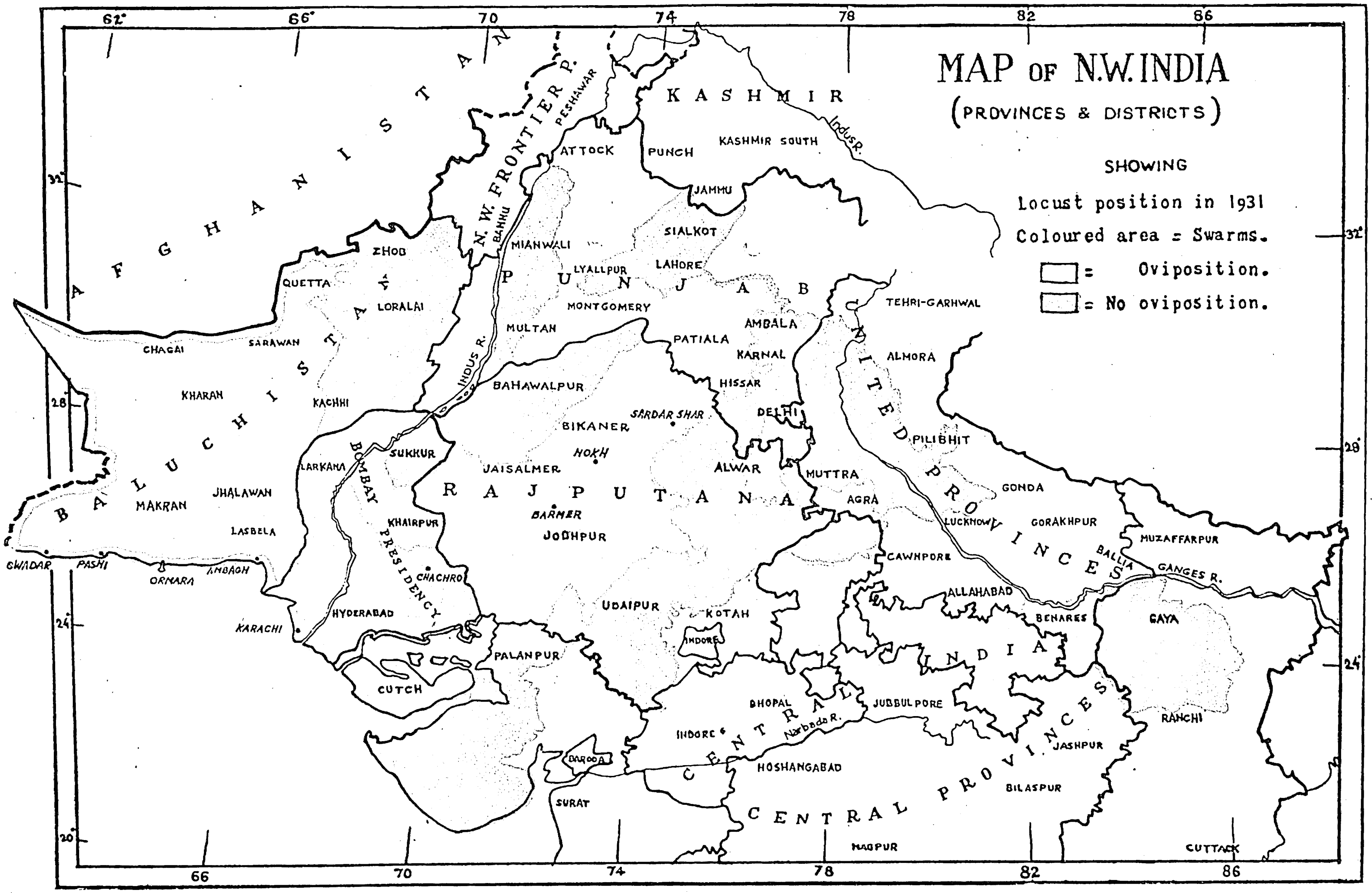
LOCUST SITUATION IN INDIA IN 1931



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THE INTERNAL ANATOMY AND DESCRIPTION OF *HEMIMERUS DECEPTUS* VAR. *OVATUS* DEORAS (DERMAPTERA), WITH REMARKS ON THE SYSTEMATIC POSITION OF HEMIMERIDÆ*

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CONTENTS

I. INTRODUCTION

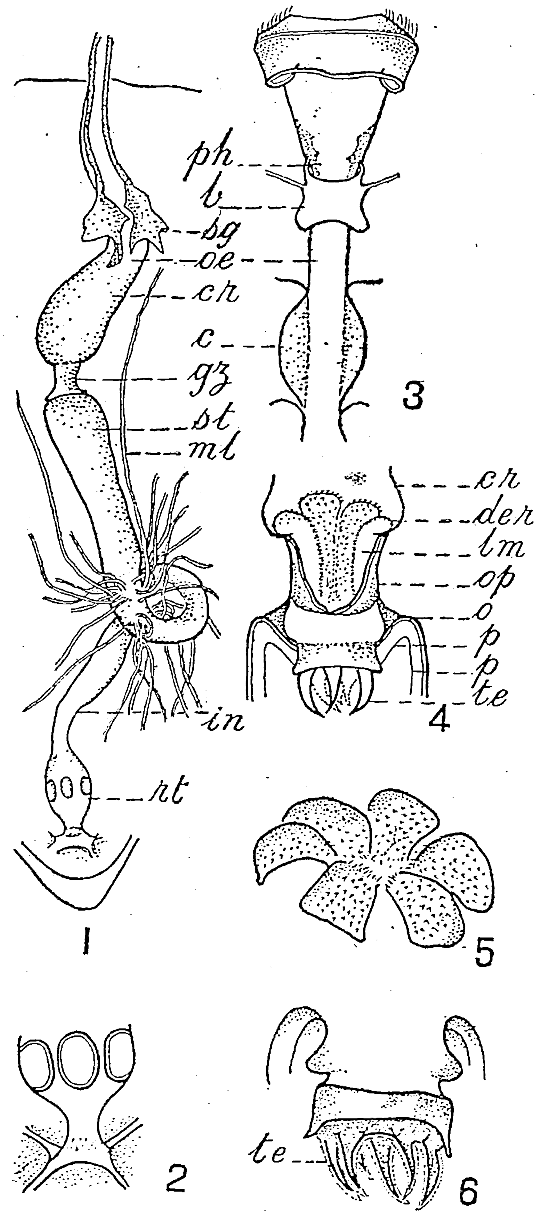
Hansen (1894) and Jordan (1909) were the earliest workers to carry out anatomical studies on *Hemimerus*. Heymons (1909 and 1912) contributed a great deal to the studies of the genital system and the embryology of the genus. Recently Rehn (1935) described a large number of species taken on the body of *Cricetomys gambianus* in South Africa.

Much however remained to be done on the internal anatomy and systematic position of *Hemimerus*. An account of the external anatomy and the relationship of *Hemimerus deceptus ovatus* to its host, has already formed the subject of a paper (Deoras, 1941); the present paper deals only with the internal anatomy and the systematic position.

II. MATERIAL AND METHODS

The material for the studies was collected in Tanganyika (East Africa); some fixed in Bouin's fluid and others preserved in alcohol.

*This work was carried out in the Zoology Department, King's College, University of Durham, Newcastle-upon-Tyne, England.



Figs. **1** to **6**. The digestive system

1. The entire digestive system; *sg.* salivary gland; *oe.* oesophagus; *cr.* crop; *gz.* proventriculus; *st.* stomach; *ml.* malpighian tubule; *in.* intestine; *rt.* rectum.

2. The rectum showing the rectal papilla.

3. The anterior part of digestive tract; *ph.* pharynx; *b.* brain; *c.* cervical region

4. A part of the proventriculus opened long itudinally, *der.* distal end of the crop, near the opening of the proventriculus; *lm.* longitudinal muscles; *op.* outer covering of the proventriculus; *o.* outer wall of the stomach that meets with the proventriculus; *p.* peritrophic membrane; *te.* teeth of the proventriculus.

5. The top of the muscles covered with spines.

6. The distal teeth of the proventriculus in an opened state.

A special method was adopted for the study of the respiratory system. The insects were kept in cold caustic potash (10%) solution for twenty-four hours, at the end of which all the internal organs were carefully washed out. They were then kept in hydrogen peroxide for twelve hours and thoroughly washed with water. After leaving them in 70% alcohol for sometime, a few drops of van Giessen's stain were added to the alcohol. After about ten seconds they were washed in 90% alcohol, dehydrated, cleared and mounted in balsam. Only the trachea took up the stain, while the other organs remained colourless.

III. Internal anatomy

Digestive system (Figs. 1-6).—The mouth opens into a buccal chamber leading into the pharynx, the sides of which are strengthened by flattened posterior arms of the suspensoria of hypopharynx. The pharynx passes through the brain and is continued as the œsophagous (Figs. 1 and 3, *oe*) in the cervical region. The œsophagous leads into the dilated crop (Fig. 1, *cr*), which extends to the first abdominal segment. On the side of the crop is a pair of salivary glands.

The crop leads into a narrow muscular region—the proventriculus or the gizzard (*gz*). The internal opening of the crop into the gizzard

(Fig. 4, *der*) is guarded by six longitudinal bands of muscles (*lm*), covered with minute spines. The posterior part of gizzard projects into the lumen of stomach, where the six bands of longitudinal muscles bear six stout curved teeth (Figs. 4 and 6, *te*). The curved ends of these can be approximated by the action of the longitudinal muscles, thus partly closing the opening of the gizzard into the stomach and acting as a cardiac valve. The stomach (Fig. 1, *st*) extends from the second to nearly the sixth abdominal segment and leads into the small intestine, which is occassionally looped at its proximal end. On the anterior part of this loop lie 24 malpighian tubules (Fig. 1, *ml*) in four groups—two anterior groups of seven, and two posterior groups of five each. The maximum length of these tubules is 6 mm.

The food in the stomach is enclosed in a peritrophic membrane (Fig. 4, *p*), hanging freely in the stomach cavity. Just in front of the entrance to hind gut, this membrane is folded upon itself, presumably acting as a pyloric valve. The rectum is ovoid (Fig. 1, *rl*), studded with six oval papillæ and is supplied with many tracheal tubes.

The contents of the digestive tract included pale scurf, bits of hair, black fungal spores, dark globules of an amorphous grey powder and some oily substance. The pale scurf resembled the external scrapings taken from the skin of the rat at the Hancock museum, Newcastle-upon-Tyne.

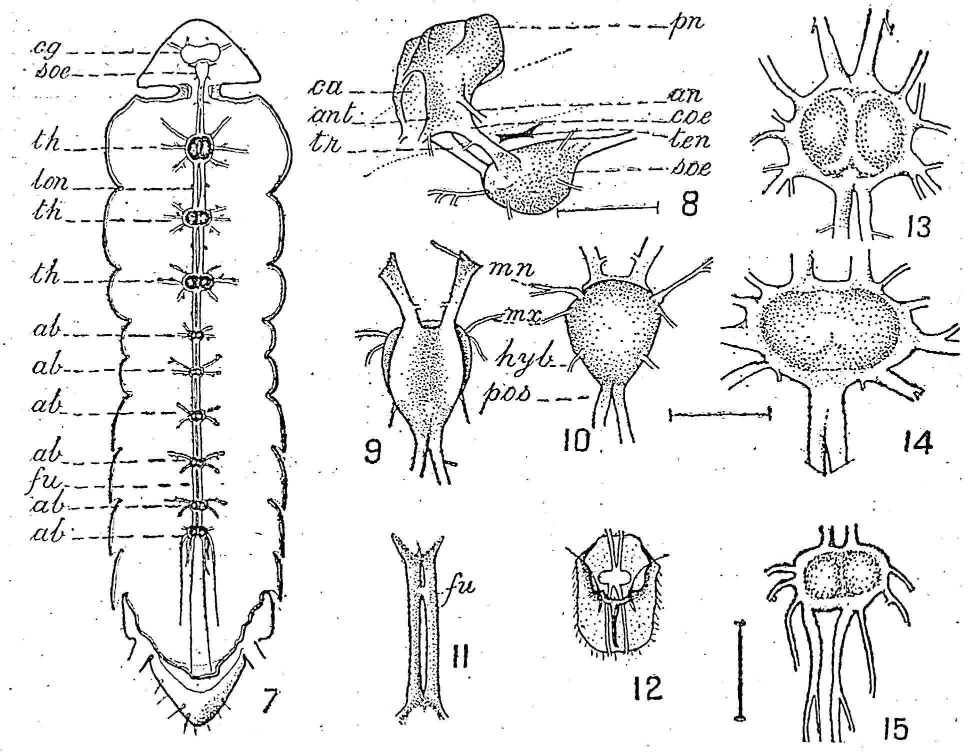
Nervous system (Figs. 7-15).—It consists of two cephalic, three thoracic and six abdominal ganglia, with longitudinal commissures between them. The cephalic ganglia consist of cerebral (Fig. 7, *cg*) and subœsophageal ganglia, connected by circumœsophageal commissures.

The cerebral ganglion is about 1 mm. in depth and has no optic lobes, but carries two small nerves (Fig. 8, *pn*) anteriorly. The deutocerebrum carries two stout nerves to the antenna (*an*), and two commissures (*coe*). The tritocerebrum has two small anterior arms (*ant*), enclosing a cavity (*ca*), through which passes the œsophagus. The anterior arms of the tritocerebrum give off two fine nerves anteriorly and also laterally, the latter meeting above the pharynx presumably form the frontal ganglion.

The subœsophageal ganglion (Figs. 9, 10) is pear-shaped, convex ventrally and flat dorsally. It gives off antero-ventrally two nerves, which bifurcate, the branches (*mn*) supply the mandibles. Another nerve (*mx*) supplies the maxilla, and a third branch (*hyb*) supplies the region of the hypopharynx and the ligula.

The first thoracic ganglion (Fig. 13) is globular and is situated between the arms of the apophyses of the first sternum. It gives off three lateral branches, which subdivide and supply the viscera. The second thoracic ganglion (Fig. 14) is bigger and lies between the apophyses of the second

sternum, giving off the same number of branches as the first. The third one is at the centre of the third sternum and gives off four branches.



Figs. **7** to **15**. The nervous system.

7. The entire nervous system (diagrammatic); *cg.* cerebral ganglion; *soc.* subœsophageal ganglion; *th.* thoracic ganglia; *lon.* longitudinal commissures; *ab.* abdominal ganglia; *fu.* fusion of the longitudinal commissure.

8. The entire brain (to scale). *pn.* anterior nerve branch of the protocerebrum; *an.* nerve to the antenna; *coe.* circumœsophageal commissure; *ten.* tentorium in section; *ca.* cavity between the arms of the cerebral ganglion; *ant.* anterior arm of the tritocerebrum; *tr.* transverse connective of the circumœsophageal commissure.

9 and **10**. The dorsal (**9**), and the ventral (**10**) views of the subœsophageal ganglion (to scale) *mn.* mandibular nerve branch; *mx.* maxillary nerve branch; *hyb.* branch to the hypopharynx; *pos.* posterior longitudinal commissure.

11. The connection in between the longitudinal commissures in the fifth abdominal region.

12. The position of the second thoracic ganglion in between the endosternites of the apophyses.

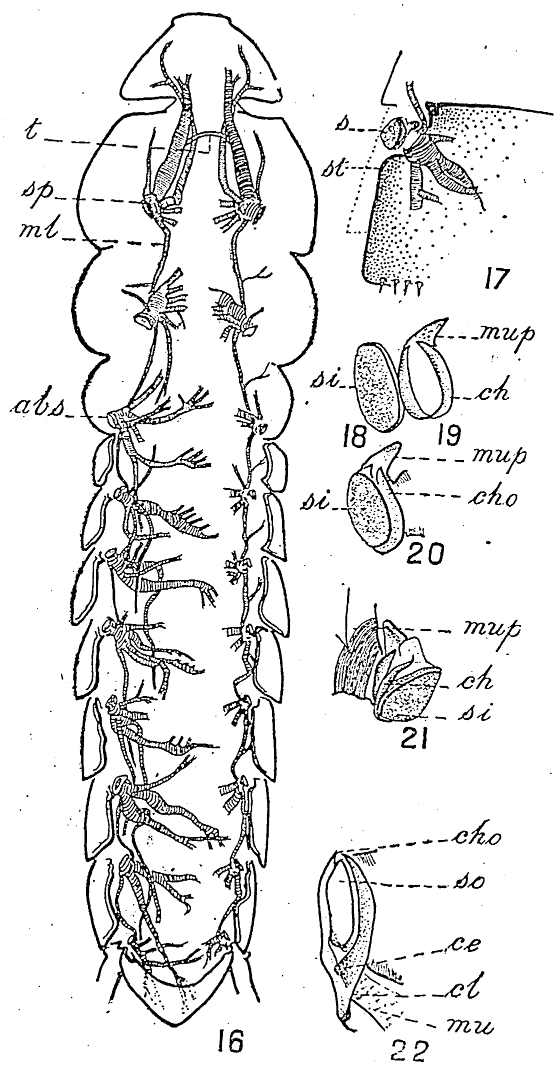
13, **14** and **15**. The 1st (**13**), and 3rd (**14**) thoracic ganglia and the last abdominal (**15**) ganglion **15** (to scale).

The first, second, third and the fourth abdominal ganglia, lie in the centre of the corresponding abdominal segments and each ganglion gives off about two lateral branches. The fifth and the sixth ganglia lie in the fifth abdominal segment and the latter is the biggest of the abdominal ganglia (Fig. 15), giving off a number of branches which reach the last segment of the animal. The longitudinal commissures (Fig. 7, *lon*),

which connect the ganglia of the trunk region, have a tendency to converge posteriorly; between the fourth and the fifth abdominal ganglia they are connected by a transverse band (Fig. 11, *fu*).

Respiratory system (Figs. 16-22).—There are ten pairs of spiracles, of which the first three lie in the thorax and the remainder in the abdomen.

The first thoracic spiracle (Fig. 16, *sp*) is elliptical and lies posterior to the epimeron of the first thoracic pleuron, above the first pair of coxæ. The spiracular opening (Fig. 22, *so*) has a hard rim surrounded by a chitinised ring, open anteriorly. The posterior part of this ring is constricted (*ce*) and underneath it are muscle-fibres (*mu*), which extend towards the coxal region. It is presumed that these muscles can close the open ends of the ring, thus partly closing the opening of the spiracle. Two pairs of tracheal tubes from this spiracle enter the head, lying over one another. The dorsal one is connected by a transverse commissure (Fig. 16, *t*) in the neck region. The second pair of the spiracle lies in the posterior region of the mesothorax and differs slightly in structure from the first. The third pair (Fig. 16, *abs*) lies in the extreme posterior region



Figs. **16** to **22**. The respiratory system. All figures are diagrammatic.

16. The entire respiratory system; *t*. transverse commissure; *sp*. first thoracic spiracle; *ml*. main longitudinal trachea; *abs*. 1st pair of abdominal spiracle.

17. Abdominal spiracle as seen from inside sternum, *s*. spiracular opening; *st*. notch where the spiracle opens.

18. The spiracular covering dissected out, *si*. sieve-like covering.

19. Lower part of the spiracular apparatus, *mup*. muscular pouch; *ch*. incomplete chitinised band.

20. An abdominal spiracle, *cho*. open end of the chitinised band.

21. Abdominal spiracle as seen from the inside. Lettering as in **19** and **20**.

22. A thoracic spiracle as seen laterally. *so*. spiracular opening; *ce*. constricted part of the outer ring; *cl*. closed end of the outer ring; *mu*. muscles.

of the metathorax and in fact belongs to the first abdominal segment, as the main branch issuing from it supplies the first abdominal segment. The structure of the third and the succeeding spiracles is similar. They consist of a chitinised circular ring surrounding a mesh-like membrane (Figs. 18, 20, 21, *si*). Under this ring lies an incomplete, circular chitinised band (Figs. 12, 21, *ch*). Anterior to its incomplete end lies a small membranous pouch (Figs. 19, 20 and 21, *mup*) the distal end of which is directed towards the body. Some muscle fibres are seen between the open ends of the band and the pouch. It appears that the closing of this opening is brought about by these muscles, which close the ends of the band.

The first abdominal spiracle lies near the first reduced sternum, while the other pairs open ventro-laterally at a notch (Fig. 17, *st*) in the respective sterna of the abdominal segments.

A longitudinal trachea runs on each side of the body connecting the main tracheal tubes. The presence of fine dust and grey powder in the trachea of many specimens, throws doubt on the efficacy of the guarding mechanism of the spiracles.

Reproductive system.—Female (Figs. 23, 24). The ovary in mature specimens consists of eight to nine panoistic ovarioles, containing one egg each. At the apex of each ovariole is a terminal filament, and posteriorly each ovariole opens into the oviduct (Fig. 23, *ovi*), which dilates and opens into the capacious uterus (*ut*). The saccular uteri end in the vagina (*vg*), which opens on the inner sides of the rudimentary eighth and ninth sterna. Heymons (1912) described the female genital system in detail and according to him the connection between the young one and the mother insect is very highly developed in this group, it may be regarded akin to the placenta of mammals.

Except for the number of articulations on the antenna, the young *Hemimerus* does not externally differ much from the adult.

Male (Figs. 25-29).—The male reproductive system is complicated and may conveniently be described under three headings : i. free-lying parts, ii. covered parts and iii. chitinised covering.

i. Free-lying parts.—consist of two coiled masses of tubular testes lying on the alimentary canal, between fat bodies and malpighian tubules. Each testis consists of two tubules (Fig. 26, *tes*). The vas deferens (*vd*) loops over the eighth tracheal trunk, runs ventral to the testis and opens into the epidedymis (Fig. 25, 26, *ep*). The epidedymis opens on the ventral side of a semi-circular membranous sac—the vesicula seminalis (Figs. 25, 26, *vs*). This sac lies over the anterior part of a muscular

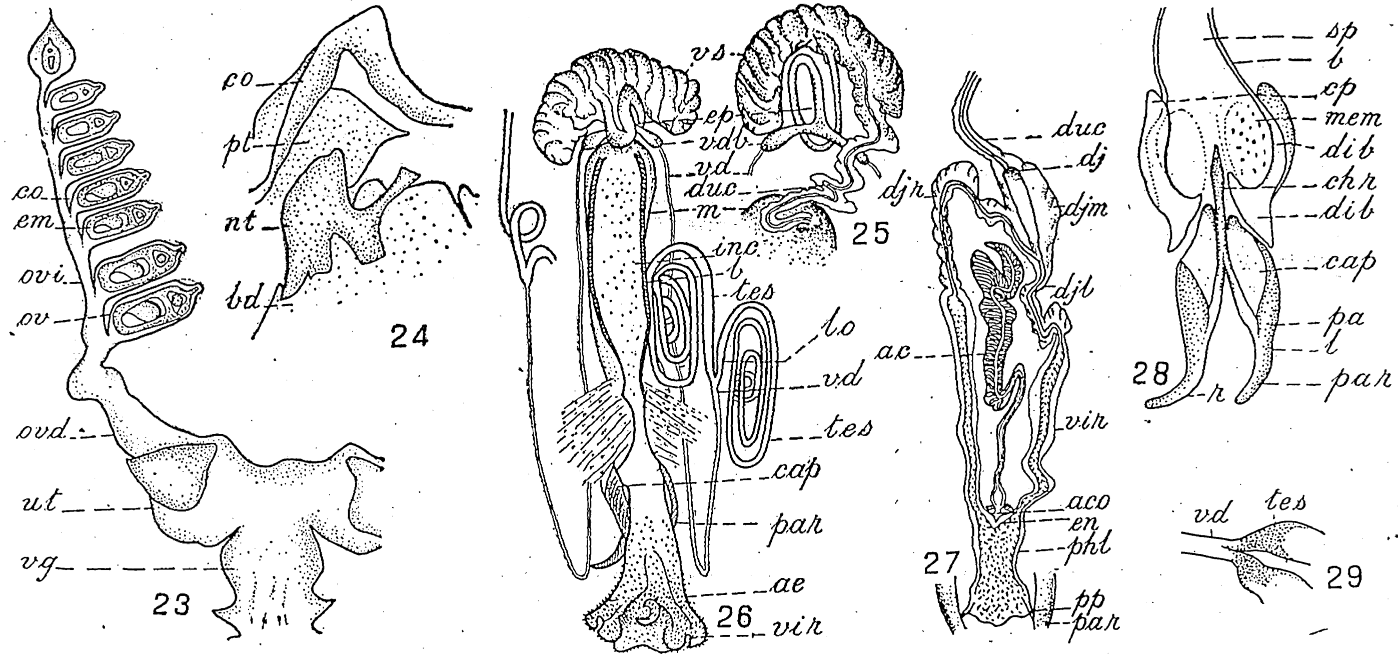
organ (*m*). The vesicula seminalis is prolonged on the left side, and encloses a thin duct which opens on the ventral side of this muscular organ. This duct is the beginning of the ductus conjunctus (Fig. 25, *duc*).

ii. Covered parts (Fig. 27).—On entering the muscular organ, the ductus conjunctus enlarges to form the ductus ejaculatorius (*dj*), from which two branches diverge posteriorly. These ducts and branches are enclosed in membranous sacs (*djm*, *djr*, and *djl*). The branches enlarge posteriorly where their lumen is beset with minute spines. This spiny enlarged region is the virga (*vir*) ; the virgæ open into a common endophallus (Fig. 27, *en*). The inner walls of the endophallus bear curved spines. The disto-lateral walls of the phallus are inserted in the cavity (*pp*) of the parameres (*par*), while the rest of the phallus lies in loose folds between them. In the everted state the loose folds of the phallus (Fig. 26 ; *ae*) and the endophallus are thrown out, thus the opening of the virgæ appear externally (Fig. 26, *vir*). Between the virgæ and ventral to the endophallus is an accessory gland (Fig. 27, *ac*) composed of small elongate tubes, within a membranous covering. This is the preputial gland, which is dilated at its opening (*aco*) in the endophallus. All the above parts lie inside the muscular organ (Fig. 26, *m*).

iii. Chitinised covering (Figs. 26, 28).—This whole region may be divided into three parts, the anterior, the central and the posterior. The anterior part (Fig. 26, *m*) covers the accessory gland and the anterior part of the ductus ejaculatorius. Dorsally it bears two chitinised bands (Fig. 26, *b*), which converge posteriorly and meet the chitinised sclerites situated there. The area between these bands is incrusted with brownish markings. In the central region, these chitinised bands (Figs. 26, *b* ; 28, *b*) are continuous with a plate of chitin (Fig. 28, *dib*), which is drawn out distally. On the inside of this plate lies an oval membranous area (*mem*), to which are attached numerous muscles. Over this area lies a crescentic plate of chitin (*cp*), which is continuous with the distal prolongation of the plate (*dib*). This central region encloses the virgæ and the phallus.

The posterior part consists of the parameres (Fig. 28, *par*) which are proximately broad and hollow, being joined by a chitinous rod (*chr*). The right one (*r*) is larger and slightly curved.

The working of the genital apparatus is presumed to be as follows : The flattened digit of the hypandrium of male depresses the last sternum of female while the parameres guide the ædeagus to the vulva. The everted endophallus attaches its spines to the walls of vagina, while the ends of the virgæ are directed towards the opening of uterus. The double opening of penis is thus evident. The rods of chitin at the proximal end of hypandrium and the abundance of muscles in that region suggest that the evertion of the penis may be almost instantaneous.



Figs. **23** to **29**. The reproductive system. All figures are diagrammatic.

23. The female genitalia. Only the right side has been shown. *co.* covering of the embryo; *em.* embryo; *ovi.* common oviduct; *ov.* ovarioles; *ovd.* dilated portion of the oviduct; *ut.* uterus; *vg.* vagina.

24. Longitudinal section of the anterior region of the embryo. *pl.* "placentahöle" (Heymons); *nt.* "nuchalorgan" (Hansen); *bdf.* body of the embryo near the cervicum.

25. The anterior part of male genitalia from ventral side. Lettering is the same as in Fig. 26.

26. The entire male genitalia as seen from the dorsal side. The lobes of the left testes are not drawn and the penis is shown everted. *vs.* vesicula seminalis; *ep.* epidedymis; *vdb.* the thickened end of vas deferens; *duc.* ductus conjunctus; *m.* muscular organ; *inc.* incrusted area between the two chitinised bands of the muscular organ; *b.* chitinised band on the muscular body; *tes.* lobe of testis; *lo.* loop of testis; *cap.* cavity of the parameres where the ædeagus is attached; *par.* parameres; *ae.* ædeagus; *vir.* virga.

27. The anatomy of the male genital part that lies covered by the muscular organ; *duc.* ductus conjunctus; *dj.* ductus ejaculatorius; *djm.* muscular covering of the ductus ejaculatorius; *djr,* right posterior covering of the ductus ejaculatorius; *djl.* left posterior covering of the ductus ejaculatorius; *ac.* the preputial gland; *aco.* opening of the accessory gland near the endophallus; *en.* endophallus; *phl.* phallus; *pp.* attachment of the phallus to the parameres

28. The chitinous distal part of the male genital organ. (Other soft parts removed). *sp.* space between the chitinised bands; *cp.* crescentic plate of chitin; *mem.* oval membranous area; *dib.* distal chitinised plates; *chr.* chitinous rod that joins the parameres; *pa.* solid end of the parameres; *r.* the right and *l.* the left paramere.

29. Showing an enlarged view of the meeting of the two lobes of the testes.

IV. Systematic position of *Hemimeridæ*

Discussing the systematic position of the genus *Hemimerus*, Hansen (1894) concluded that " it belonged to Orthoptera, constituting a separate family, very closely allied to the Forficulidæ ". Jordan (1909) observed that " *Hemimerus* and *Arexenia* do not indicate a close relationship ". Rehn (1935) thinks that the suborder Hemimerina is more closely related to Arexinina and Forficulina, than to any other group of insects.

To trace the systematic position of Hemimeridæ one has to look for its resemblances to both primitive as well as highly evolved Orders of insects.

The Hemimeridæ have the following points in common with Thysanura :

i. Abdomen with 11 segments
ii. The presence of hypopharynx with superlinguæ
iii. The mandible with a prostheca
iv. The glossæ and the paraglossæ reduced to a single lobe as in *Japyx*, that is, the reduction of the four-lobed condition to a bilobed one.

The points of resemblances between Hemimeridæ and Orthoptera are :

i. The general shape and structure of head, thorax and abdomen.
ii. The wingless condition of certain Blattidæ
iii. The reduction of the tarsal joints from five to three
iv. The presence of vivipary as in *Panchlora viridis*.

The two-lobed condition in *Perla immarginata* (Hoke, 1924), and the suspected presence of the double nature of the opening of the penis (Walker, 1922) in the order Plecoptera shows a slight resemblance to the Hemimeridæ.

The same remarks apply to the order Ephemeroptera, which exhibits the two-lobed ligula, superlinguæ and also the double nature of the opening of the penis.

Members of the genus *Hemimerus* are external parasites and so are the insects belonging to Mallophaga. The parasitic mode of life in both these groups have modified the organs of the body in various ways, as a result of analogous parallel evolution. Many points of resemblances are thus seen, such as the shape of the body, absence of eyes and wings, and reduction of many other parts of the body.

The features so characteristic of the family Hemimeridæ, are met with in the suborder Fortificulina, especially the superfamily Labiduridæ :

i. The apterous condition (*Anisolabis*)

ii. The eighth and the ninth tergites greatly reduced. The tenth sternum is reduced in both cases and lies over the bases of the cerci

iii. The opening of the male genital duct is paired in *Labidura* and *Anisolabis*

iv. The structure of the alimentary canal, especially the mid-intestine with teeth and the peritrophic membrane as seen in *Hemimerus*, occurs in Forficula (Wigglsworth, 1930).

It then seems clear that the family Hemimeridæ has several characters in common with primitive orders like Thysanura and also a little more highly evolved orders like Ephemeroptera. Walker (1922), in discussing the phylogeny of the Orthopteroid insects, has drawn a phylogenitic tree in which he includes all the above orders and some more, as being derived from a hypothetical order Palæodictyoptera.

The nearness to Dermaptera especially Forficulina, is further evident from the following: *Hemimerus* is totally blind, has hairy unsegmented cerci, and shows a tendency towards apterous condition, further the degree of parasitisation is doubtful. The suborder Forficulina includes some insects which have straight hairy cerci, show a tendency towards apterous and eyeless condition, a bilobed ligula and a paired opening of penis. *Hemimerus* shows primitive characters, while the suborder Forficulina contains highly evolved forms such as Forficula, as well as primitive ones like *Anisolabis* and *Labidura*. It therefore appears that the systematic position of the Hemimeridæ probably lies within the suborder Forficulina.

Burr (1915) stated that "true earwigs fall into two groups—those with a pair of penes, the Protodermaptera, and those with one, the Eudermaptera". He also added "that *Arixenia* and *Hemimerus* come near to Eudermaptera, for there is a single direct preputial sac and ejaculatory duct". Jordan (1909) mentions that the ductus ejaculatorius seems to divide where it enters the outer half of the organ of copulation, but he was not sure on the point.

Snodgrass (1936) says, "the exit ducts of *Hemimerus* open separately into the end sac of the penis—there can be no doubt that the organ has been produced by the union of the two penes, having the structure of the paired organs of Labiduroidæ".

From the description of the male genital organs, it is quite clear to me that the ejaculatory duct and the penis opening in *Hemimerus* is double. In view of this fact and those stated above, I believe that the family Hemimeridæ should be classed under Protodermaptera of Burr (1915).

It has been mentioned by Burr (1915) "that *Arixenia* was Eudermapterous and so were families Forficulidæ, Labiidæ, and Chelisochidæ".

In the same work the two superfamilies Protodermaptera and Eudermaptera are placed in the suborder Forficulina. Two separate suborders Hemimerina and Arixenina have been erected to receive just one family each, *i.e.*, Hemimeridæ and Arixeniidæ. Thus under the present system of classification the order Dermaptera is divided into three suborders, namely, Forficulina, Hemimerina and Arixenina, the last two consisting of one family each.

From the above discussion it is clear that *Hemimerus* is nearest in relationship to insects like *Anisolabis* and *Labidura*, of the family Labiduridæ. The present system of classification of the order Dermaptera is based on such characters as the shape of the forceps, nature of abdomen and pygidium. These factors are very variable. The character that seems most constant in these insects is the nature of the opening of the penis, *i.e.*, double or single. Considering the similarities between the families Hemimeridæ with Labiduridæ and also between Arixeniidæ and Forficulidæ, it seems possible to simplify the classification of Dermaptera as given below. The families in the first series are given in the order of the complete double nature of the opening to the partial union of the ejaculatory duct.

Order Dermaptera

Series 1. *Protodermaptera*

Families—Labiduridæ, Pygidicranidæ, Apachyidæ, Hemimeridæ

Series 2. *Eudermaptera*

Families—Arixeniidæ, Labiidæ, Cheliosochidæ, Forficulidæ

The main characters of the first series are the same as given by Burr (1915), *i.e.*, double ducti ejaculatorius and the double opening of the penis. In the second series both of these are single.

It will be seen that the other characters of the families grouped in the above series are more or less similar and make them a group. A detailed classification of the order Dermaptera is out of the scope of the present work and, therefore, these other characters are not discussed. I have tried to show how the family Hemimeridæ could be re-classified after considering its affinities to the family Labiduridæ. It is hoped that a detailed study in this direction may alter the classification of Boremans and Krauss (1900) and Burr (1915).

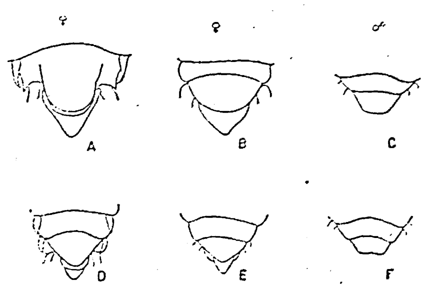


Fig. 30. A.B.C.—The distal abdominal parts of *Hemimerus deceptus* Rehn, var. *ovatus* Deoras. D.E.F.—The distal abdominal parts of *Hemimerus deceptus* Rehn (after Rehn).

The present specimens are nearly akin to *Hemimerus deceptus* Rehn, but there are many differences in detail. These are described below, while an indication of this new variety has previously appeared in a preliminary note (Deoras, 1940).

Hemimerus deceptus Rehn	*Hemimerus deceptus ovatus* Deoras
1. Length of body from Labrum to pygidium, female—9.8 to 10.5mm. male—9.8 to 10.7mm.	1. Length of the body from labrum to pygidium, female—11.8mm (average of 25 spiecmens) male—11.6mm.
2. In female the proximolateral sulciform impressions are variable in their extent and prominence, the dextral always broader and more deeply excavated than the sinistral	2. There is no apparent difference between the dextral and the sinistral proximo-lateral sulciform impressions
3. The marginal carina of the last abdominal sternum in female is sub-obtusely angulate. (Fig. 30, D)	3. The marginal carina in the female is ovate (Fig. 30, A)
4. In female the distal margin of the last abdominal tergite is curved to a sub-obtusely angulate mid point. (Fig. 30, E)	4. The distal margin of the last abdominal tergite is conical and converges evenly to a midpoint (Fig. 30, B)
5. In male the median length of the ultimate tergum is equal to the three-fifths of the apical width	5. The median length of the ultimate tergum is half the width
6. In male the lateral margins of the penultimate tergite are subtruncate and the distal margin has a wide concavity. (Fig. 30, F)	6. It is evenly rounded and the distal margin has a narrow concavity. (Fig. 30, C)
7. The mesothorax is the widest segment in both male and female.	7. The prothorax is the widest segment in both male and female.

From the above it appears that there are two races of *Hemimerus deceptus*. One race occurs in Transvaal and the other in Tanganyika. Two specimens, male and female, have been deposited in the British Museum of Natural History, London.

Hemimerus deceptus ovatus—Type.—Male and female, Morrogoro, N. E. Africa. Characters.—Head, thorax, abdomen, and the other features are the same as that of *H. deceptus* Rehn., except for the differences enumerated above, with regard to the last abdominal segment, size of body, lateral impressions and geographical distribution.

V. Acknowledgments

The work was done under the supervision of Dr. D. Stewart MacLagan, to whom the author owes a deep debt of gratitude. Prof. A. D. Hobson gave all possible facilities for the work in his department and systematically criticised the work. My thanks are due to Dr. Hinton for confirming my identification of the insect. The specimens were collected by Mr. W. V. Harris in Tanganyika. I have to express my sincere thanks to the Trustees of the Hindu Education Fund, Bombay, for the financial aid. I am also much thankful to Dr. Hem Singh Pruthi, Imperial Entomologist, New Delhi, for his kindness in going through the manuscript.

VI. Summary

The anatomy of the digestive, nervous, respiratory and reproductive systems of *Hemimerus deceptus* var. *ovatus* is described in detail. The important features are the primitive characters of the nervous system, spiracular opening, and the double nature of the ejaculatory duct, as well as the double opening of the penis. After a brief review of the affinities, this insect is shown to be allied to the suborder Forficulina. An attempt has been made to simplify Burr's (1915) classification of the order Dermaptera

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SHORT NOTES AND EXHIBITS

Progress of the Locust Cycle of 1940

In the last two issues of this Journal [2 (2) : 241, 1940 and 3(1) : 139, 1941] I reported about the commencement of a fresh cycle of the desert locust in India in the autumn of 1940 and described its development up to April 1941. During the last summer there has been very heavy swarming of the locust; this is briefly described below :—

As already reported, there was no incipient swarming in Baluchistan during the last spring and early summer, which is one of the important sources for the swarms for Rajputana and other parts of India. From the end of June up to the first week of August two principal waves of immigrant swarms came from countries beyond the western borders of India. They flew over the whole of Rajputana and western Indian states, touching Hissar in the east and some western districts of the Punjab in the north, but they laid eggs mostly in the Lasbela State (Baluchistan), Tharparkar District (Sind), Kutch and Tharad States (western India), western parts of Jodhpur State, etc., which received fair amount of rainfall in August. Active breeding was in progress in these areas during July-September. Oviposition took place on several occasions and by the end of August hoppers of all stages were met with. The hoppers started becoming adults from the end of August onwards. The largest number of swarms originated from Tharparkar District of Sind, but Lasbela, Kutch, Jaisalmer, and some areas in Rajputana also contributed some swarms. The swarms which originated from Sind, Lasbela and Jaisalmer mostly flew in north and north-east direction and invaded the cultivated areas of North Sind, Khairpur and Bahawalpur States, south-eastern districts of Baluchistan and southern and south-western districts of the Punjab. The swarms originating from eastern Rajputana states also flew mostly from south-west to north-east direction and visited Alwar, Hissar, Muttra and Aligarh districts in the east, and in the southern direction the swarms flew over Bhopal and Indore in Central India and Hoshangabad, Nagpur and some other districts in the Central Provinces. These home-bred swarms laid eggs in several parts of Rajputana, Alwar and Gwalior States, Muttra and Aligarh districts of United Provinces. One swarm reached Madras Presidency.

As the oviposition by the first batch of swarms took place in several series and breeding of second generation also started about the middle of September, we are having swarms up to the present date (25th November 1941). It would be recalled that last year the swarms continued to be active in north-west India right up to the end of December and restarted their activity in February.

New Delhi, November 26, 1941 HEM SINGH PRUTHI

Raising of a pure stock of *Bemisia tabaci* for virus transmission

Although specimens of *Bemisia tabaci* commonly occur on numerous host-plants almost throughout the year, it is not desirable to directly employ such specimens in experiments, as the results are invariably vitiated by the possibility of their already having ingested the virus by feeding on diseased

plants in Nature. Two methods were evolved in the course of experiments performed during 1936-41 :

(*i*) One or two gravid females, collected from the field, were enclosed in a micro-cage with a leaf of a healthy tobacco plant inside a larger cage for egg-laying. Soon after the eggs had hatched, the nymphs were transferred to another healthy plant and were allowed to develop into adults. In many cases the plant on which the eggs were first laid, ultimately developed leaf-curl as a result of feeding by the adult-flies, while the plant to which the nymphs were subsequently transferred remained healthy.

(*ii*) A few white-fly pupæ were collected with a piece of its food-plant and were fixed on a healthy tobacco leaf by small pins through the outer leaf tissue without injuring the pupæ and allowed to remain until the adults had emerged. In no case did the disease develop on the plant on which the pupæ were reared into adults.

New Delhi C. K. SAMUEL

Phthorimœa operculella (Zeller) as a pest of potato leaves

Phthorimœa operculella is a very important pest of stored potato in almost all parts of the world. In America and South Africa the species is also well known as a destructive miner in tobacco leaves and to a lesser extent in potato leaves. In India it has not so far been found as a pest in the field, its ravages being confined to the stored tubers only. It is known to mine potato leaves but the attack is seldom severe. During my visit to Dharwar (Bombay Presidency) about the end of September 1941, I found that this insect was breeding in alarming numbers on potato plants. The leaves were badly mined and etiolated. Hundreds of moths were sheltering under small clods and cracks of the soil. On being disturbed, they come out in small swarms but settled down and concealed themselves in the soil immediately. The tubers under the soil were healthy but the danger to the crop which was due to be harvested shortly is quite apparent

New Delhi GHULAM ULLAH

Some Butterflies from Delhi

Though butterflies of the plains of India have been very extensively studied, very little exact information is available regarding their seasonal abundance, flight and other habits. About 60 species belonging to over half a dozen families occurring in Delhi and its environs were collected and studied by the writer.

Most of the species were very common in gardens, sucking nectar from their favourite flowers, but *Colotis* spp. (Pieridæ) were observed in stony and open places, sparsely covered with such semi-xerophytic plants as *Capparis aphylla* and *Boarhaavia repanda*. The Danaid *Europea core* prefers moist and shady to open places, while others like *Papilio polytes* and *Papilio aristolochiæ* (Papilionidæ) prefer sheltering under bushes in the gardens. *Ixias* spp. (Pieridæ) are generally found where *Copparis sepiaria* and *Capparis spinarum* grew in abundance.

The males are more active than the females in the movements. In some butterflies, like *Mypolimnas misippus*, *Zizera mahamaha* and *Zizera trochilus putli*, the males appear to be somewhat pugnacious in their courtship.

Hours between 10 A.M.—3 P.M. are ideal for collection of most of the species, which are usually found on their favourite flowers at this time, while most of them are rarely on wings in the early morning and late evening hours.

Dusty, windy and rainy days are not favourable for butterfly collection, as these generally remain sheltering under bushes and dense foliage of plants.

A further detailed account is under preparation.

New Delhi, 19-ix-1941 A. S. JANDU

Arcyophora dentula Hamps., A new pest of pomegranate

Arcyophora dentula (Acontianæ : Noctuidæ) was originally described by Hampson in 1912 from specimens captured on wing. In 1940, I collected some caterpillars on pomegranate at New Delhi and reared the moths.

The distribution of the species is as below : Syria, Mardin, Iran, Mesopotamia, Western Turkistan, South Ferghana, and from the Punjab, Campbellpur, Bombay and Mhow in India. The present is the first record from Delhi.

The capterillars gnaw holes in leaves, leaving at first the epidermis of one side intact, in between veins but ultimately almost entirely defoliating the plant in considerable numbers from the middle of September to the middle of October.

The caterpillars are uniformly light green, sparsely studded with long hyaline hairs. When full-grown, the caterpillar spins a white conical silken cocoon, reinforced by soil particles in which it pupates. The pupa is yellowish-brown ; lighter at the tail end and the ventral surface, purplish-brown in the intersegmental depressions ; spiracles brown ; penultimate abdominal segment fringed with hairs at its posterior dorsal margin.

New Delhi T. D. MUKERJEE

Feeding habits of some Mantids

Though a considerable amount of work on the general habits of Mantidæ has been done, very little information is indeed available on their feeding habits ; this perhaps is due to the extreme difficulty of breeding Mantids in captivity on account of their truly voracious nature.

A species of *Hierodula*, common in Delhi, was studied in the laboratory of Imperial Entomologist. Several dead and living insects were given as food. During its life-time of about 2 months, a single adult fed on over 150 insects, belonging to numerous orders. During this period, owing to unavoidable circumstances, the Mantid starved for nearly 20 days on the whole—thus it would have consumed much more than it actually did if food were available. Indeed it was found to finish off within a day half a dozen specimens of the *ak* grass-hopper, a similar number of butterflies and moths. Its daily bill of fare included the following :—*Poecilocerus pictus*—full grown nymphs—5, *Acrida exaltata*—4, *Utetheisa pulchella* adults —1, a Mantid nymph—1, a Lygeid nymph —1. Adults of *Utetheisa, Danaida, Papilio demoleus*, Syntomids, Lyceinids and caterpillars of *Utetheisa*, Nymphalids, Pyralids and Pierids, Jassids, *Engytatus* and *Metacanthus* were also included in the list. From this it is obvious that the role played by various species of Mantids in keeping important pests under check in Nature is not small.

New Delhi P. B. MOOKHERJEE

A Note on *Myllocerus lætivirens* Marshall (Curculionidæ)

This weevil is found in Delhi on a variety of plants but it is most abundant

on a hedge-plant, *Schinus terebinthefolius*. The adults heavily damage the tender leaves of plum and almond, which also appear to be their favourite food. Other food plants are pear, apricot, pomegranate, cotton, apple, citrus, lucerne and *Grewia asiatica*. They are attracted to light in small numbers. The beetles feed very actively only at night and appear in enormous numbers after showers of rain.

Towards the end of June, the beetles copulate. A single female lays about 40-45 eggs. The eggs are creamy-yellow, translucent, 0.6 mm. long and 0.25 mm. broad. The incubation period is 4-5 days. The larvæ, soon after hatching, are very active, and creamy-yellow in colour. The grubs feed on the roots of the food-plants and die if the roots get dried up. The adults are preyed upon by a spider and a Mantid, *Empusa pauperata* F. Hibernation occurs in the larval stage underground near roots of their food-plants. The weevils are not attracted to light.

New Delhi M. Bose

Gall-formation in paddy by *Pachydiplosis oryzae* Mani

While investigating the *gangai* disease of paddy caused by *Pachydiplosis oryzae* Mani, an interesting observation was made with regard to the formation of the gall. The leaf sheath is normally in a rolled condition and this roll is opened by a mechanical push of the incoming leaf. So long as this gradual push does not take place, the leaf-sheath continues to remain closed. In attacked plants, the maggots reach the soft, juicy growing-tip of the stem and feed upon them. The preceding leaf with its rolled-up sheath is getting the nutriment and grows as there is no mechanical stimulus for its opening, it remains closed. The tissues at its edges grow into each other and form a tube. The colour of the tube is like that of the sheath. Histological studies confirm the view that the tube is a modified sheath. It is hoped to publish the results in detail.

New Delhi, 19-ix-1941 P. J. Deoras

Record of the tent caterpillar from Simla Hills (Punjab)

Malacosoma indica Wlk. was collected infesting apple, pear, apricot, *shegal* (*Pyrus pashia* Ham.) and walnut in Simla Hills for the first time.

Its life-history was studied in broad outline. The moth lays its eggs on branches in ring-like masses of 300-400. Eggs laid in May-June hatch in March next and the larval and pupal stages take 39-68 and 8-20 days respectively, thus completing one generation in a year.

Lyallpur Khan A. Rahman

Occurrence of the gypsy-moth *Lymantria obfuscata* Wlk. in Simla Hills

Caterpillars of this species were found damaging apples at Kotgarh, Gopalpur, Rhoga, Pomlai, Loshta and Aino. They spend the day hiding in the soil under the infested plants and feed at night. They continue feeding actively during April-May and pupate in June.

Lyallpur Khan A. Rahman

A serius mite pest of fig at Lyallpur

The mite *Eriophyes* sp. infests the under surface of the leaves where it forms galls. The infested leaves dry and fall off. The pest is active throughout summer but when the leaf-fall begins in November, the mite migrates to the branches and passes the winter underneath the terminal bud-scales.

Lyallpur A. N. SAPRA

New host plants of *Laphygma exigua* Hübn.

Moths of *Laphygma exigua* were reared from larvæ feeding on *oont chara* (*Heliotropium europæum*) and *lani* (*Sualda fruticosa*) at Lyallpur. This is the first record of these caterpillars feeding on these hosts.

Lyallpur M. A. GHANI

An unusual mode of oviposition in the desert locust

The desert locust *Schistocerca gregaria* Forsk has been well known to oviposit in tubular pockets in the soil and measures for the destruction of the eggs have been based on this habit. Recently, however, a swarm of locusts that visited the Muttra district of the U. P. behaved differently. The locusts rested over an area of approximately a square mile and dropped their eggs on the surface of ground, accompanied by the white fluffy material, secreted by them during normal oviposition. The eggs thus laid were estimated to weigh nearly two maunds.

The oviposition ground was a waste land having a very hard surface and it is conceivable that the female found it impossible to bore into it. At the same time there were a few fields quite close by lying fallow which were not so hard for oviposition. A physical feature common to both, however, was their extreme dryness which may have prevented the insects from ovipositing in the normal manner. An examination of the eggs showed that they were normal and fully mature. It seems, therefore, that dryness and not hardness of the soil so much induced the locusts to depart from their normal method of oviposition and being in urgent physiological necessity to get rid of their eggs they were impelled to merely drop them on the surface of the ground. Needless to say such eggs could hardly be expected to hatch, having been exposed to the desiccating action of sun and air and to the attentions of numerous natural enemies. The phenomenon is also of great importance from the standpoint of locust control because if eggs are to be deposited in this fashion they obviate the necessity of control measures. So far as is known to the present writer no locusts are recorded to possess the habit of normally scattering their eggs on ground surface.*

Cawnpore, 21.xi.41 K. B. LAL

Effect of rainfall on the emergence of *Dorysthenes hugeli* (Redt.)

The apple root-borer is a serious pest of apple trees in the Kumaon hills. It has a fairly long life-history, extending over four years, during most of which the larvæ develop inside thick roots of apple trees and appear as adult beetles in the beginning of the monsoon. Observations over many years have

*A similar phenomenon was recently observed in Alwar, where a swarm resting on trees simply threw down their eggs. [Ed.]

shown that the emergence of the beetles from pupæ depends largely on the incidence of rainfall during the previous eight or nine months. For instance, at Chaubattia (near Ranikhet) and Ramgarh (near Bhowali) the adults have been usually observed to emerge about the beginning of July, soon after the first showers of rain have fallen. But this emergence may be delayed if there is frequent rainfall during the previous spring and early summer, which presumably slows down the rate of pupal development, with the result that the emergence of adult in the following July is delayed, even though there has been a rainfall. On the other hand, if the spring and early summer have been fairly dry, development of the insect proceeds normally and the beetle waits for a fall of rain to emerge as adult. The latter condition happened in 1941, when the spring passed off fairly dry and monsoon broke out towards the end of May. The beetles, therefore, appeared much earlier than their usual time, the first specimen having been caught on the 31st May at a verandah light.

Incidentally it may also be mentioned that while both sexes of the beetle are positively phototropic, only males preponderate in light-trap collections.

Cawnpore, 21.xi.1941 K. B. LAL and R. N. SINGH

Relative incidence of *Dacus ciliatus* Loew and *Dacus cucurbitæ* Coq.

From some maggot-infested fruits of *Luffa aegyptiaca* Mill., kept for the rearing of fruit-flies on 31st October, flies started emerging on 10.xi.1941 and continued doing so up to 16th November. These flies belonged to two species: *Dacus cucurbitæ* Coq. and *Dacus ciliatus* Loew. It was found that *Dacus ciliatus* was predominant. The ratio between the two species as observed in one case, was *Dacus ciliatus* Loew. 71 and *Dacus cucurbitæ* Coq. 26, which roughly works out at 3 : 1.

Cawnpore P. L. CHATURVEDI

Incidence of sugarcane pests in south Bihar during 1940-41

From observations made in the fields of Rhotas Sugar Mills, Dalmianagar, and South Bihar Sugar Mills, Bhita, the incidence of different borers on sugarcane was found to be generally lower than in the northern areas of the province. The incidence of *Diatraea auricilia* was, however, distinctly higher than those of the top-shoot and root-borers, though this was not so in the north. Further, the number of plants attacked by *Aleurolobus* and *Pyrilla* were smaller in the south than in the north. This is perhaps explained by topographical and climatic differences between the north and south of Bihar. In the latter area, the soil is very little water-logged. Further, in the same area several other crops had already germinated earlier than sugarcane, thus probably serving as alternate food-plants and attracting the borers away from sugarcane.

Pusa A. C. SEN

Sex-ratios and eye-stripes in a swarm of the desert locust

I observed a swarm at Ajmer in the Government College grounds between 11 A. M. and 12-30 P. M. on September 18, 1941. It disappeared from the grounds a little after mid-day. The directions of flight were irregular and rapidly changing, and could not, therefore, be determined for the swarm as a whole. As locusts flew very low it was easy to catch them, but they did not settle down on the ground.

Dr. B. L. Rawat, Professor of Zoology at the College, collected some locusts at random from the swarm, through whose courtesy, I was enabled to examine them with the following results :

Sex-ratios.—21 males and 7 females *viz*., 3 : 1.

Eye-stripes.—In all cases, except three males, there were 6 clear eye-stripes. In the three exceptional males, the eye-stripes could not be clearly counted. All the individuals were " yellow " and, therefore, presumably mature.

Calcutta M. L. ROONWAL

Parlatoria pseudopyri Kuwana—a synonym of P. oleæ or P. cinerea Hadden ?

Takahashi [*Proc. R. ent. Soc. London*, (B) 7 (12) : 271-272, 1938] described *Parlatoria pseodopyri* Kuwana as occurring at Lyallpur and Bhakar in the Punjab and Shab Qadar, in the N. W. F. Province. Rahman (*Final Report on the Combined Entomological Scheme, Punjab and N. W. F. Province*, 1940), basing his identification on the above work, reports it to be present on apple, mango, *phalsa* (*Grewia asiatica*), rose, jasmine, *Nerium* sp. and *dharek*. On re-examination of the specimens, however, it appears that Takahashi found them to be identical with *Parlatoria oleae* (Colvée), for in a reprint of his paper recently sent to me, I find that he has corrected with hand *P. pseodopyri* Kuwana as *Parlatoria oleae* (Colvee). The validity of *P. pseodopyri* had long been doubted since Kuwana [*Byochu-Gai Zasshi* (*J. Plant Prot.*), Tokyo, 19 : 8-17, 1932] described it. Morrison [*U. S. Dept. Agric. Misc. Pub.*, 344 : 34 (1939)] clearly stated that it is a synonym of *P. cinerea* Hadden. As *P. oleae* and *P. cinerea* can be easily distinguished from each other by several important characteristics, it is not known whether the Indian specimens sent to Takahashi really belong to the species *P. oleae* or *P. cinerea*. In view of this confusion and before the error creeps into other Indian entomological literature, it would be worthwhile re-examining the specimens from the original collection. It would be interesting if this scale proves to be *P. cinerea*, for, though this insect has been intercepted by the U. S. A. Plant Quarantine Service from plants received from India, there is so far no record of it from India itself. This again shows the urgent need for a more thorough taxonomic survey of Indian scale-insects and for the establishment of Plant Quarantine.

Coimbatore, 25-ix-1941 V. PRABHAKER RA

RECENT RESEARCH

Relation between Insect Vectors and Plant Viruses

It is well known that all insects are not equally good vectors of vario plant viruses and the efficacy of a vector in the case of the same virus is depen ent on the duration of its feeding period on the infected plant and whether it h fed or fasted before such feeding. The work of Watson & Roberts [*Proc. Soc.*, (*B.*) 127, 1939 & *Ann. appl. Biol.*, 27 (2), 1940] has thrown a great deal light on this subject. These authors worked with three strains of *Hyoscyam*

virus 3, two of cucumber virus 1, and potato virus Y. The vectors, *Myzus persicæ, M. circumflexus* and *Macrosiphum gei* were under test. The efficiency of the vectors increased with increasing times of fasting before feeding on the infected plants and it decreased as the period of feeding on the infected plants increased. *Myzus persicæ* proved to be the most successful vector and *Macrosiphum gei* the least successful ; but the relative efficiency of the vectors varied with different viruses. The authors explain the above on the assumption that the viruses are inactivated by some substance produced by the aphids when feeding and that the capacity of various vectors for inactivating a virus is not equal, *Myzus persicæ* having the lowest capacity on the whole. This activating substance is considered to be produced after about 2 minutes' feeding.

The authors further conclude that the various viruses can be grouped into "persistant" and "non-persistant" categories. The viruses mentioned above which get inactivated during the feeding of the vectors on the infected plants are called "non-persistant." The loss of activity is not considered to be due to cleansing of the stylets when feeding or to the normal deterioration of the virus when fasting. Persistant viruses are not affected by the inactivating substance and the vectors acquire lasting infectivity. Thus most of the major differences between the results of various transmission experiments with the two types of viruses could be accounted for by differences in the effect of the inactivating substance produced by the vectors. H. S. P.

Communal disaffection in ants

Communal affection among ants is well known and when ants belonging to different nests affiliate, live amicably for some days, cleaning one another and inter-regurgitating, the union is ususally believed to be permanent. This, however, is not always quite true ; ant queens sometimes fight each other and the workers, previously at peace with all members of the nest, even take sides with the fighting queens. This, for instance, is the case with *Formica subsericea*, recently investigated by Lafleur [*J. N. Y. ent. Soc.*, **49** (2) : 199, 1941]. The queens of this species were observed to live together peacefully for over one year, before they showed signs of communal disaffection. These apparently sudden outbreaks of hostilities between "friendly" queens synchronised more or less with the maturation and emergence of workers in the nest. Lafleur concludes that the clue to this extra-ordinary behaviour of the queens lies probably in the urge for acquiring a large brood of workers. He believes in a sort of "emotion of jealousy" between the queens, leading to the fight for advantages of a larger brood. The author believes that the fact that it is much easier to affiliate queens and workers than queens and queens lends support to this view. Workers also remain friendly with any individual they get acquainted with in their first days of life, so that if a queen were driven away or murdered, at this critical period they remain loyal to the surviving queen. M. S. M.

The Parasite *Trichogramma evanescens* Westw. race *minutum* (Riley) as a controlling agent of sugarcane borers

Experts are divided in their opinion on the efficacy of *Trichogramma evanescens minutum* (Riley) in the control of sugarcane borers and on the causes of failures and achievements. Jaynes and Bynum [*U. S. Dept. Agric. tech. Bull.*, **743** : 1-42, 1941] have recently carried but experiments to ascertain whether or not the sugarcane borer (*Diatræa saccharalis* F.) in Louisiana could be controlled by mass liberations of this parasite. In evaluating the results of release of *Trichogramma*, it was found important to obtain all information likely to be useful in interpreting the data. It was found that *Trichogramma* dispersed as far as 100 feet within 48 hours after release. A definite correlation was shown to exist between the percentage of parasitism and host density. Parasites were released at the rate of 10,000 to 45,000 per acre during the three seasons. In comparing the progress of the parasitisation of the borer, very little difference was observed between the percentages of parasitisation in the colonised, buffer and check plots. A study of the infestation in the stalk and joint showed that the borer infestation in the plots in which *Trichogramma* were released increased to as great an extent as in the check plots. No relationship was evident between *Trichogramma* releases and increased yields. The authors concluded that " the results of the experiments conducted during the three seasons show that the releases of *Trichogramma* are of no value in the control of the sugarcane borer in Louisiana and so the colonisation of *Trichogramma* as a field practice for the control of the sugarcane borer is therefore not recommended." T. V. V.

Racial segregation in insect populations

The habits of a species are usually supposed to be as fixed as its specific morphological characters and are not expected to change within less than quasi-geological periods of time. Therefore the control programmes of economic entomologists generally follow the taxonomists' classification of morphological races. Smith [*J. econ. Ent.*, **34** (1) : 1-12, 1941] reviews the literature on the practical significance of continuous segregation of what are known as physiological races with important differences in habits and physiological and ecological characteristics although they are apparently indistinguishable from one another in their structure. For example, it is shown that four species of scale insects have within the life time of one entomologist evolved races which are harder to kill by certain insecticidal treatment than the ordinary population of those species or than any of their populations of say twenty five years ago.

The author cites numerous examples showing how the tendency to form races complicates the problem of insecticidal or mechanical control, breeding of resistant hosts and of plant quarantine. He tries to explain the formation of these races with the help of the principles of genetics and evolution and presents a valuable meeting ground for the geneticists, the physiologists, ecologists taxonomists and economic entomologists. S. P

Mosquito control

In recent years a great deal of work has been done on the control of malaria-transmitting mosquitoes and the present war has given a new impetus to it. All the different theories on malaria transmission maintain that the causal organism *Plasmodium* is of three or four species, producing in man clinically different varieties of the disease, and that the developmental cycle of the parasite takes place only in mosquitoes of the genus *Anopheles*, which is represented by 150 species in different parts of the world.

Wigglesworth writing on "Malaria and war" [*Nature*, **147** (3728) : 436, 1941], mentions in detail the following important species of *Anopheles* causing malaria in different parts of the world : *A. maculipennis* in England, many parts of Europe and coastal belt of Tripolitania, *A. superpictus* in the eastern Mediterranean, *A. pharoensis* in Egypt, *A. multicola* in north-west Africa, *A. gambiae* in west Africa and *A. subpictus*, *A. culicifacies*, and some others in India. He then discusses the different theories of mosquito control. Sinton and Shute [*Minist. Hlth. Memo.*, No. 238 H. M. Office, London, 1940] have recorded 29 species of mosquitoes from Great Britain, 19 of which are of importance and have reviewed the methods of their control during different seasons. Herms and Gray [*Mosquito control*, Oxford University Press, London, 1940] have also discussed the problem from all the aspects.

It is generally agreed that mosquitoes could be controlled either in the adult stage, so that there would be no more oviposition, or in the larval stage to prevent further breeding. Twinn [*Dom. Can. Dept. Ag. Div. Ent. Publ.*, No. 719. *Circular* No. 62, 1941] has given a very lucid account of the control of adult mosquitoes by putting nets on windows, by netting them in the dark corners of the houses and by the use of sprays and repellants. The main constituent of the sprays is pyrethrum at the rate of 1 lb. to 1 gallon of kerosene oil. For field sprays, light fuel oil, as well as some liquid potash-soap are added to these sprays. The repellants are generally made of citronella oil. MacNay's formula quoted by Twinn is quite good.

The control of the immature stages is effected by permanent and temporary measures. The permanent measures consist of proper drainage or siphoning [MacDonald, *J. mal. Inst. India*, **2** (1) : 63, 1939]; Tweedie, *J. Malaya Br. Brit. med. Ass.*, **4** (2) : 167, 1940]. Smith [*Nature*, **147** (3732) : 576, 1941] cites how thousands of lives were saved in the last war by these measures. The temporary measures are confined to biological as well as technical methods. MacCay & Senior-White [*Indian med. Gaz.*, **76** (1) : 37, 1941] report that certain prawns destroy mosquito larvae in large numbers. Van der plank [*E. Africa med. J.*, **17** (10) : 431, 1941] mentions that *Northobranchimus* as well as fishes of genus *Barbus* control Anopheline larvae. Similarly the introduction of sticklebacks, gold-fishes and larger fishes check the breeding in weedy ponds of Anopheline larvae. Ramsay [*Trans. R. Soc. trop. med. Hyg.*, **23** : 511, 1930] mentions that in Bengal and Assam *A. minimus* was checked if bushes were properly planted

along streams. Thompson [*J. malar. Inst. India*, **3** : 265, 1940] advocates the flooding of streams in the centre. Manson [*J. mal. Inst. India*, **2** (1) : 85, 1939] mentions certain plants as being deterrant to mosquito breeding.

The chemical measures are confined to larvicidal methods. A thin stable film of oil (15 Microns thick) is spread over the water to suffocate the larvae. Murry [*Bull. ent. Res.*, **27** : 287, 1936 ; **29** : 11, 1939 ; **30** : 211, 1939,] advocates the use of spreaders. Castor-oil is a good spreader and cresol increases the toxicity of the larvicidal oil. Petrol is good for storage waters and a thin layer of liquid paraffin prevents the insects from oviposition. In weedy ponds this oil is to be mixed with saw dust. Surface-feeding larvae are destroyed by paris green mixed with some inert dust such as sand, powdered soapstone, or slaked lime. Liquid pyrethrum-kerosene larvicides are being largely used, as they are harmless to fish, waterfowl, water plants sewage and disposal bacteria.

Hardy [*Ent. month. Mag.*, (4) **20** (927) : 169, 1941] mentions that yellow colour keeps mosquitoes away. These views have yet to be confirmed.

P. J. DEORAS

NEW BOOKS AND MONOGRAPHS

An Introduction to Entomology. By J. H. Comstock, (Ninth edition) revised by G. W. Herrick. 8vo., cloth, Pp. 1064, figs. 1228, Ithaca, N. Y. : Comstock Publishing Co., Inc., 1940. Price $5.00.

Insect Pests. By W. C. Harvey and H. Hill. Pp. ix+292, figs. 23, London : Lewis & Co., 1940. Price 10s. 6d.

Mosquitoes of the Ethiopian Region. 3 : Culicine adults and pupæ. By F. W. Edwards. Pp. viii +499, 4 pls. London : British Museum (Natural History), 1941.

Indirect methods of Insect Control. By Isley, D. (Second Edition) Minneapolis : Burges Pub. Co., 1941, Pp. 121. $1.5.

ECONOMIC ENTOMOLOGY OF SOUTH INDIA

Dr. T. V. Ramakrishna Ayyar is a veteran entomologist whose contributions to Indian economic entomology are many and varied. He has crowned his previous achievements by writing a " Handbook of Economic Entomology for South India " (Government Press, Madras, 1940—Price Rs. 4/12/-), which though ostensibly meant for South India, is bound to prove of value to students and workers on entomology all over the country, since many of the insect forms treated therein are widely distributed in India. The book contains 500 pages and is divided into two parts. Part I deals with the general morphology, physiology and classification of insects. Part II contains accounts of important pests of various crops and fruit trees together with descriptions of methods for their control. A chapter on such beneficial insects as bees and silkworms is included and the book ends with five appendices some of which are very useful. The format and get-up of the book are highly commendable.

It should not, however, cause any serious detraction from the merit of the book to say that it misses first-rate production in several respects, and these should be pointed out if only for the reason that the second edition of the book should appear as free from criticism as possible. A general impression after reading the book is that the author does not seem to have paid much attention to the work on economic en-

tomology during the past ten years. The accounts of such important pests as the spotted and pink boll-worms of cotton, the cotton stem-weevil, the moth borers of sugarcane, etc., in the study of which considerable advances have been made, appear to be based largely on investigations carried out before 1930. The author still considers the San José scale and the codling moth as foreign pests, whereas actually the former is definitely known from India since 1919 and the latter since 1935. In Part I one fails to see marked reference in the accounts on the general physiology of insects and of their metamorphosis, the morphology of insect genitalia, etc., to the recent and outstanding contributions of such authors as Wigglesworth, Snodgrass, Pruthi and others.

Some aspects of applied entomology, for instance, the question of evolving and growing of plant varieties resistant to various insect pests, may have been given more than a mere passing reference (p. 97). Similarly locusts, though not a problem in South India, may well have deserved at least a page of description, in view of their overwhelming importance to Indian Agriculture. There are several agricultural crops which suffer from virus disease through insects transmitting plant viruses in South India are hardly known so far. Among non-insect pests of crops, mites should have received more adequate attention than almost a passing reference.

Some of the names used by the author have long been superseded by new names, *e.g.*, *Heliothis obsoleta* by *H. armigera*, *Estigmene* by *Amsacta*, *Zonabris* by *Mylabris*, etc. On page 436, the specific name of the head louse is given as *Pediculus capitis* and that of the body louse *P. corporis*. In the figures given, however, the latter is shown as *P. humanus*. Neither is correct, as both the lice have long been shown to belong to one species, *P. humanus*, having two forms, *capitis* and *corporis*. In several cases, the same species (even on the same page) has been ascribed to different authors, *e.g.*, *Sphenoptera gossypii* to K. and again to C. (p. 240) Not much uniformity has been observed in abbreviating the names of authors, witness for example Distant being abbreviated as D. and Dt. on the same page (p. 144), De Geer as D. and again as deG. (pp. 409 and 438). In this connection it may also be remarked that the practice of abbreviating the names of authors by a single letter is open to very serious objection and the only exception that may possibly be permitted is that of Linnaeus. Again, several species have been ascribed to wrong authors *e.g.*, *Cryptothrips occulta* (p. 259), *Omphisa anastomosatis* (p. 262), etc.

The author does not appear to have been careful in seeing the book through the press. A large number of even important pests have been spelt wrongly, *e.g.*, *Diatraea*, *Scripophaga*, *Asamangulia*, *Asphondylia*, *Empoasca devastans*, etc. The book also contains many press mistakes and errors. Capital letters have been used indiscriminately, for example, Lepidoptera has been spelt both with a capital letter (p. 77) and a small letter (p. 19). Whereas all family names of insects should end with dipthong 'ae', in the book no difference has been made between this dipthong and 'oe' Some families end in 'ae' and others in 'oe'. The word 'mug' for 'bug' on page 196 is a bad misprint.

There are numerous very useful illustrations in the book but unfortunately a number of them have not been reproduced properly. Some figures (*e.g.*, on pages 81 and 221) are too small to serve any useful purpose, while others (*e.g.* on pages 69, 308 and 309) are unnecessarily too large. Some of the figures have been oriented wrongly (see pages 269 and 424). In the case of several pests quite good illustrations have been published in recent years but the author has selected rather unsatisfactory figures published long ago or those published in other countries.

In a review of this book published in *Curr. Sci.*, 8 : 376-378, 1941, some errors in regard to the identification and nomenclature of lac and lac insects have been mentioned and certain other features of the book have also been pointed out. It is not necessary, however, to repeat them here to agree with much of what that reviewer has said.

In spite of all the criticisms, the book ranks as an outstanding contribution to Indian entomological literature and must long remain on the tables of students

of entomology all over the country. If the reviewer were asked to point out the greatest single merit of the book, the answer would unhesitatingly be the very broad outlook with which the subject of economic entomology has been treated in it, embracing such apparently academic topics as mimicry and parental care in insects to name only two. To those impatient enthusiasts, who will have our agricultural students learn nothing more of economic entomology than the popular names of some pests and the cut-and-dried formulæ of their control the following words of the author must be commended for hard thinking : " When once we get an idea of the ways of an insect pest, methods of control become a matter of common sense ". But not till then. K. B. L.

ADAPTIVE COLOURATION IN ANIMALS*

The book is not strictly entomological, yet no entomologist, whatever his special line of research, can afford to ignore it if he is to understand his insects well. Entomological research in India is almost exclusively confined to morphological and bionomical work. Experimental research on comparative physiology is in infancy. Those researches which generally go under the comprehensive heading of " natural history " are almost ridiculed. Indeed, natural history, especially such phenomena as mimicry, warning colouration and the like, are looked askance outside India as well. In the present book Dr. Cott has with one bound " turned the table with a vengeance " on such objectors. He has gathered together in an impressive manner almost everything about the adaptive colouration of animals, and what is more important, he has elucidated the principles involved. Naturally he has taken his examples from among all the groups of animals. But, as everyone knows, insects provide some of the most striking of such examples and Dr. Cott has made the fullest use of them.

The book is divided into three parts. Part I deals with "Concealment" wherein such topics as general and variable colour resemblance, obliterative shading, disruptive colouration, concealment of the shadow, and finally, the function of concealing colouration in nature are dealt with in detail and with great clarity. Nor does the author omit to discuss fairly the objections that have from time to time been raised against the theory of concealing colouration.

Part II deals with " Advertisement. " The author first discusses the methods by which conspicuousness is attained in nature, and details under this heading such particulars as the appearance and behaviour of aposematic animals, warning displays and adventitious warning colouration. He then goes on to describe warning colouration in reference to prey and to predatory animals.

Part III covers " Disguise " wherein, among other devices, one species sails under false colours of another and better protected species. First, special protective and aggressive resemblances are discussed, such as, for example, special resemblance to particular objects, adaptive behaviour in relation to special cryptic resemblance and adventitious concealing colouration. Another section deals with conspicuous localised characters among animals, such as deflective and directive marks. The last section deals with alluring and mimetic resemblances. Mimicry is dealt with in great detail.

The above is a brief outline of what treasures the book contains. For every topic the author discusses, dozens of examples are taken from insects, and in such phenomena as mimicry, insects provide the most numerous and conclusive examples.

The beautiful and instructive illustrations, of which there are many, are among the chief attractions of the book. Let no entomologist ignore this classical work. M. L. R.

* Hugh B. Cott. (With an Introduction by Julian S. Huxley)—Metheun & Co. Ltd., London 1940, 508 pp.

FOREST INSECTS OF INDIA*

Dr. C. F. C. Beeson, till recently Forest Entomologist, Dehra Dun, has done good service to Indian entomology by publishing a book on forest insects, which is based on the author's personal experience extending over 25 years. The publication of the book was undertaken to provide a cheap and portable manual of pests and the methods of their control for forest officers and their staff as well as a work of reference for research officers and entomologists. The book has just over 1000 pages and apart from to the first few introductory chapters, consists of two parts : Part 1—" The ecology of forest insects," and Part 2—" The control of forest insects." Over 4000 species of insects are enumerated.

We are afraid the titles selected for the two parts are not very appropriate, because the first part, which is supposed to concern with the ecology of insects, chiefly contains accounts of the systematic position, anatomy, life-history, etc., of the insects enumerated and there is very little ecology as the term is understood to convey at present,—the behaviour of insects as influenced by various factors of environments including climate, food, natural enemies, etc. On the other hand, general ecology of various insects is described in the second part which also deals with their control. In fact the arrangement followed in Part II is better in principle because it is very useful if the account of ecology of insect pests immediately precedes the suggestions regarding control measures. Actually one would have preferred if the author had amalgamated both parts into one and given the complete account (systematic, distribution, habits, ecology, control methods, etc.) of a particular pest at one place.

The arrangement which the author has adopted in dealing with various pests will not perhaps be easy to follow by those for whom the book is primarily written, *viz.*, forest officers. He has arranged various insects according to orders, families, genera and species, all arranged in alphabetical order rather than according to any system of classification. The great advantage of the latter system would have been that after reading the accounts of pests belonging to one order, say Rhynchota, the readers would have incidently learnt about the habits and general control measures regarding all other pests of this order which are not described in the book or which may assume importance in future. For example, according to the system followed by the author, the account of Anopleura is followed by that of Coleoptera and in the order Coleoptera account of a scavanger family is followed by a phytophagous family and so on. Accounts of related groups having their names beginning with different letters have per force been given at different places in the book. In view of this, one cannot read the book with sustained interest. The book therefore appears to be a dictionary in this respect.

Furthermore, the forest officers will find it difficult to trace the account of a particular pest. The author presumes that they will at least know the name of the insect concerned or type of damage it does. Even if a forest officer knows all the names, which is not likely, he will be able to trace the information easily because the scientific name by which he knows an insect may not be the one adopted by the author of the book and further the author has not given synonymies of even important insect pests either in the text or in the index. The names of authors of species are also not given. As regards the mode of damage, the reader in many cases will be confronted with over 8 orders

*Forest Insects—The Ecology and Control of the Forest Insects of India and the neighbouring Countries. The Vasant Press, Dehra Dun : 1941, Price Rs. 12/8/-

of insects which do the same kind of damage and then under various orders he may have to see through all the families of such big orders as Lepidoptera and Coleoptera. This is specially true in the case of defoliators, predators insects living on decaying vegetable matter, etc. For example, predators are found in numerous families of Hymenoptera, Neuroptera, Odonata, Rhynchota, Coleoptera, etc., while scavangeras are met with in most families of Collembola, Psocoptera, Isoptera, Thysanura, etc. Moreover, the author has omitted to give the usual list of contents in the beginning of the book and has not mentioned the names of all the orders in Part II, and the few which are mentioned are printed in such a manner as to look having the same rank as families. It will therefore be often much more easy for a forest officer to write to a central entomological station for the name of the insect than to trace it in this book. It would have been better if the use of alphabetical arrangement had only been restricted to genera and species.

Subject to the above criticism, the book is very exhaustive and a virtual mine of information. However, there are certain points in which entomologists would like the book to be improved. In the use of carbon bisulphide, a very common fumigant, the dosage of 60-80 oz. per 1000 c.ft. of space is recommended (p. 863), whereas for using it to disinfect books and seeds in storage doses of 32 oz. and 16 oz. per 1000 c. ft. respectively are given. Actually it is in the case of empty space that the dosage should be less than in the case of grain, or other material. Further, the author has emphasized that while fumigating grain the weight of the grain should be kept in view and not the space in which the latter is kept. Actually both have to be kept in view because it is obvious that the quantity of the grain remaining the same, the dosage depends on whether it fills a godown or say, the grain occupies only $\frac{1}{4}$ space, and on the size of empty space.

The control methods for various pests have on the whole been described rather very briefly. For example, in the case of spraying, it would have been useful to general readers such as forest officers, if the methods of preparation of insecticides, time, number and periodicity of spraying, etc., had been described. The recommendation for the control of red hairy caterpillars by hand picking and squeezing will be questioned by many workers. The use of one md. of bait per 1-$1\frac{1}{2}$ acres for locusts will be wasteful. The dose of 1 % sodium arsenate (presumbly the author means sodium arsenite) for termite control (p. 949) will prove injurious to many seedlings. In the chapter on 'poisons', fumigants, etc., important insecticides, *e.g.*, sodium arsenite and the most important fumigant HCN, have not been described. While stating important conclusions which are the results of recent research it would have been useful to research workers if the authors of the views had been quoted. There are a few inaccurate statements : for example, *Odinadiplosis odinae* is described as forming galls on *Launea grandis* (p. 434), while really it produces galls on *Odina wodier.* The pH range 6.2-8.6 is not 'very alkaline,' as has been stated by the author.

The book is very well written and there are only a few misprints and typographical mistakes. The beginning of a sentence or paragraph with the words " E. G. " is rather unusual and some words seem to have dropped off on pp. 857 and 865 during printing. The punctuation in titles, headings, etc., is not uniform. The laudable object of keeping down the cost of production seems to have been carried too far and the get-up of the book has severely suffered and several figures otherwise good have been very much crowded together, and in some cases got mutilated, obviously during binding. It would have been better if the 'Manual' had been more portable.

In the end, we must congratulate the author for the publication of this monumental work—a work which was badly needed, as the last account of the forest insects of India was publishecd about 30 years ago and undoubtedly research on insects has made considerable progress during this period.

HEM SINGH PRUTHI

NEWS AND ANNOUNCEMENTS

The Scheme of Research of ICAR for Regional survey of sugarcane borers was closed on the 30th November. With effect from April 1942, the Imperial Council of Agricultural Research proposes to start a large scheme, under which various methods of control of cane pests, particularly the use of parasites, will be on extensive trial in several Provinces.

The Department of Agriculture, United Provinces, has appointed special staff for the extermination of San José scale in the Kumaon hills.

The University of Agra has decided to institute a course in Entomology for the M.Sc. degree in Agriculture.

The U.P. branch of the Entomological Society of India was inaugurated at Cawnpore on the 22nd November, 1941.

Rao Bahadur Y. Ramchandra Rao, Locust Research Entomologist, Imperial Council of Agricultural Research, retired from service on 31st March, 1941.

Dr. T. V. Ramkrishna Ayyar, formerly Entomologist to Government, Madras, and the retiring President of the Entomological Society of India, has been appointed Entomologist to H.E.H. The Nizam's Government, Hyderabad.

Mr. J. C. M. Gardner has been appointed Forest Entomologist, Forest Research Institute, Dehra Dun, *vice* Dr. C. F. C. Beeson retired. Mr. A. H. Khan has been appointed Systematic Entomologist, *vice* Mr. J. C. M. Gardner.

Dr. E. S. Narayanan, Ph.D. (Lond.), has been appointed Second Assistant Entomologist, Imperial Agricultural Research Institute, *vice* Dr. K. B. Lal. From September 1941, Dr. Narayanan is now officiating as Biological Control Research Officer, *vice* Dr. J. A. Muliyil on leave, and Mr. B. B. Bose is officiating as Second Assistant Entomologist.

Dr. Taskhir Ahmad, Assistant Entomologist, Imperial Agricultural Research Institute, took over charge of the current duties of the Second Entomologist in addition to his own with effect from 1st August 1941, from Mr. P. V. Isaac granted leave.

Obituaries

Mr. H. L. Bhatia (1901-41)

Mr. Hira Lal Bhatia, a foundation member, passed away at Lahore unexpectedly at a very young age, after a brief illness. The late Mr. Bhatia, son of Lala Ram Lal Bhatia, Advocate, High Court, Lahore, was born in September, 1901. He was educated in the Central Model School, Lahore, and he joined the Punjab University in 1917. He took his degree in 1921 with Honours in Zoology topping the list of successful students and thus winning the University scholarship and prizes. After taking M. Sc. from the same University in 1923, he took up appointments successively as Professor of Biology in the Ramjahs College, Delhi, and Hindu College, Amritsar. In 1927 he joined the Entomological Section of the Imperial Agricultural Research Institute, where during the past thirteen years he worked on various aspects of Entomology, specially the biology and systematics of flies. For a couple of years during this period he was deputed to work as Entomologist at the Imperial Veterinary Research Institute, Mukteswar.

During the last two years or so he was mostly working as the Assistant Locust Entomologist and visited and organized locust control work in almost all the States in Rajputana and Baluchistan.

Bhatia was not a narrow specialist but took an almost archimedian interest in all entomological matters. He was the Joint Secretary of the Entomological Society of India in 1941. He was the author of several very important papers on Indian Diptera.

The death of Bhatia leaves a big gap in the entomological workers of this country, as he had attained the first rank among the workers on Diptera in India and the adjoining countries. At Mukteswar he was the first to be successful in transmitting the notorious Rinderpest disease by means of a Tabanid fly. By nature, Bhatia was simple, rather modest and shy. His genial temperament endeared him to all with whom he came in contact in his official atmosphere or in private life. He leaves a very large number of friends at the Imperial Agricultural Research Institute, New Delhi, to mourn his loss and we extend our heartfelt sympathy to Mrs. Bhatia and children.

We regret to announce the following other deaths:

Dr. V. G. Deshpande, M. Ag., Ph. D., Professor of Entomology, Poona College of Agriculture, on August 22nd, 1941, at the age of 51. He joined the Agricultural College, Poona in 1920 as a Lecturer in Entomology and was appointed Professor of Entomology in 1938. Deshpande took the B. Ag. diploma in 1913, M. Ag. degree in 1927, and Ph. D. from the Edinburgh University in 1930. He mostly worked on Aphididæ and Aleurodidæ.

Dr. Lee A. strong, Chief of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, on June 2, 1941. Dr. Strong was born in 1886. He worked for 19 years in California. In 1929 Dr. Strong was appointed Chief of the Bureau of Plant Quarantine, U. S. A., which was amalgamated with the Bureau of Entomology in 1934 and he became the Chief of the newly established Bureau of Entomology and Plant Quarantine. During 30 years of his work, Dr. Strong made important contributions to entomology, specially in reference to the problems of insect quarantine.

Dr. H. Eltringham, F.R.S., on November 26, 1941, aged 68. Dr. Eltringham was well known for devising technique for the study of insect anatomy and histology and for his work on Lepidoptera. He was a very enthusiastic Fellow of the Royal Entomological Society of London, of which he was Secretary or President for some years.

PROCEEDINGS OF THE ENTOMOLOGICAL SOCIETY OF INDIA

(Up to November 1941)

DELHI BRANCH—NEW DELHI

14th July

Exhibits

An interesting Coccid, *Pulvinaria* sp. from Delhi—GHULAMULLAH.

Some butterflies of Delhi—ARJAN SINGH.

Poecilocerus pictus on fig trees. This is the first record of this grasshopper feeding on fig and extremely interesting in that the adults feed on fruits in preference to leaves—B. B. BOSE.*

Arcyophora dentula breeding on pomegranate. This pest is previously known to occur in Syria, Mardin, Persia, Mesopotamia and South Farghana but is being recorded from India on pomegranate for the first time—T. D. MUKERJEE.

* Fletcher [*Proc. III ent. Meet., Pusa*, p. 307 (1920)] has already recorded *Pœciloceus pictus* as a pest of figs in South India; the present record is not therefore the first.—M. S. Mani.

Communications

Two methods of rearing pure stock of white-flies for virus transmission experiments—C. K. SAMUEL.

On the morphological changes in Trichoptera in different habitats—P. J. DEORAS.

Aphids and some other Rhynchota from Afghanistan—GHULAMULLAH.

Aphelinus mali in the Kulu Valley (Punjab)—H. S. PRUTHI.

19th September

Exhibits

Some irridescent-coloured beetles—An important feature in the beetles exhibited was that their colour varied with the angle of light and vision as a result of refraction and defraction effects due to structural peculiarities of elytra—SHER KHAN.

New host-plants of *Poecilocerus pictus*. Nymphs and adults of this grass-hopper were collected feeding on leaves of *Barleria prionitis* and *Clerodendron* sp.—ARJAN SINGH.

Zeuzera coffeae caterpillar boring into shoots of peach from Dehra Dun district—M. BOSE.

Chloebra crassa and *Odalis senegalensis* in Dwarka. Hoppers of these species were found breeding in large numbers on grass in Okhamandal and Jamnagar. Slight damage to *bajri* was noticed—H. L. BHATIA.

Communications

Further observations on *Myllocerus laetivirens*. A brief account of the biology of the pest was given.—M. BOSE.

Feeding habits of some Mantids—P. B. MUKERJEE.

Gall-formation in paddy by *Pachydiplosis oryzae*—P. J. DEORAS.

Orientation of desert locust hoppers during different parts of the day—S. MUKERJI.

PUNJAB BRANCH—LYALLPUR

13th May

Communication

Mallophaga on *Gallus domesticus*—M. A. RAHMAN.

17th June

Communication

The cotton Jassid, *Empoasca devastans* Dist.—MANZOOR ABBAS.

20th September

Communication

Some important pests of hill fruit trees—A. W. KHAN.

15th October

Communication

Trypanea amnoea and its parasites—K. N. TREHAN.

BIHAR BRANCH—PUSA

15th November

Communication

Goniozus indicus Ashm. (-*cuttockensis* Lal) parasite of *Emmalocera depressella*—TAZIM-UL-HAQUE.

Pyrilla control work—L. N. NIGAM and A. C. SEN.

Deterioration in the quality of cane juice due to borers—L. N. NIGAM.

Exhibits

Goniozus indicus (different stages)—TAZIM-UL-HAQUE.

SOUTH INDIAN BRANCH—COIMBATORE

18th November

Communications

Life-history notes on *Grammodes stolida* Fabr., a pest of *daincha* (*Sesbania bispinosa*)—M. C. CHERIAN and C. V. SUNDARAM.

Habrobracon hebetor (Say), a parasite on *Dichomeris ianthe* infesting lucerne—P. N. KRISHNA AYYAR.

Exhibits

Tarache notabilis Wlk. (Noctuidæ) appeared as a very severe pest on cotton in October 1937 in the Cotton-breeding Station at Coimbatore. Long cycle pupæ were found and moths sometimes emerged from the soil after 18 months. *Tricholyga sarbillans*, Wied (Tachinidæ) occurred as a parasite on the caterpillar of *Tarache notabilis* during the same season. *Actia monticolla* Mall. (Tachinidae), another parasite on *Tarache notabilis*, is not so numerous as *Tricholyga*. *Macroplectra nararia* Moon, a Limacodid caterpillar appeared as a pest defoliating *Pithecolobium dulce* in Coimbatore in December 1937. *Fornicia ceylonica* Wlk. (Braconidæ) a sigalphine larval parasite of *Macroplectra nararia*. A single parasite issues from each host. *Chelonus formosaria*—Braconidæ—The parasite was bred from *Prodenia Litura* caterpillars on castor. It is an egg parasite and oviposits in one-day old eggs of the host. The host eggs hatch in the normal way into caterpillars and the parasitic eggs hatch subsequently in the body of the host and develop inside along with the host; a single grub comes out of each host and pupates in the soil. From each egg mass of the host about 100-200 parasites can be reared out. *Apate submedia* Wlk. This Bostrychid was found boring into living mango stems and branches at Udumalpet in 1935. As many as 5-6 tunnels were found in badly infested branches. The trees are said to die off in the course of a few years—M. C. CHERIAN.

A Carabid predator on *Sylepta derogata*.

Eublemma scitula, Eublemma silicula and *Eublemma trifasciata*—predaceous on Coccids on cotton. The last two are new records of their predaceous habits on Coccids—P. N. KRISHNA AYYAR.

Dermestes cadaverius Fb. (Dermestidæ) found doing considerable damage to stored groundnut kernals in the godowns at Pondicherry in March 1941. *Gonocephalum* sp. (Tenebrionidæ) found in large numbers in bags containing stored groundnut kernels at Pondicherry

in March 1941, but no actual damage reported. *Rhogas percurrens* Lyle. (Braconidæ)—a specific parasite of *Achaea janata* caterpillars. *Micropilitis maculipennis* Szép. Another specific parasite of *Achaea jenata* caterpillars in the early stages—MOHD. BASHEER.

U. P. BRANCH—CAWNPORE

22nd November

General

The branch was inaugurated by Dr. Taskhir Ahmad, the General Secretary of the Entomological Society of India. Dr. K. B. Lal and Mr. P. L. Chaturvedi were elected respectively President and Secretary of the Branch Society.

Communications

Life-history of *Enarmonia pseudonectis* Meyr.—K. M. GUPTA.

The effect of rainfall on the emergence of the apple-root borer, *Dorysthenes hugeli* (Redt.) (= Lophosternus hügeli), in Kuamon hills—K. B. LAL and R. N. SINGH.

Exhibits

Dacus cucurbitae Coq. and *Dacus ciliatus* Loew bred from *torai* fruit at Cawnpore—P. L. CHATURVEDI.

Eggs of *Schistocerca gregaria* Forsk. found scattered on dry soil surface—K. B. LAL.

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